Demand Side Management in Agricultural sector of Uttar Pradesh - Investment Strategies and Pilot Design.

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By

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Rural Electrification Corporation
Electronics Corporation of India Limited
R & D wing of All India Radio, New Delhi
Uttar Pradesh State Electricity Board
Punjab State Electricity Board

ACRONYMS & ABBREVIATIONS

AIR	All India Radio
CCU	Central Control Unit
CEA	Central Electricity Authority
CT	Current Transformer
DF	Diversity Factor
DSM	Demand Side Management
DT	Distribution transformers
FM	Frequency Modulation
hp	Horse Power
kHz	Kilo Hertz
kM	Kilometer
kV	Kilo Volt
kW	Kilo Watt
kWh	Kilo Watt hour
Lakh	10^5
LT	Low Tension
MHZ	Mega Hertz
mu	Million Units
MW	Mega Watt
MWh	Mega Watt hour
Paise	1/100 th of a rupee
PTW	Private Tube well
RDS	Radio Data System
REC	Rural Electrification Corporation
RPM	Rotation per Minute
Rs.	Rupees
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition System
SEB	State Electricity Board
UHF	Ultra High Frequency
UIW	Unit Irrigation Work
UPSEB	Uttar Pradesh State Electricity Board
VHF	Very High Frequency

Executive Summary

1. Objectives

This report seeks to:

- Survey maintenance practices and attitudes towards the efficient consumption of electric power in rural areas (*Chapter 2*)
- Establish the technical potential for conserving electric power in the agricultural sector of UP through a pilot program of rectification of private lift irrigation pumps (Chapter 3)
- Estimate the load profile of agricultural consumers through an analysis of load curves of selected rural feeders (Chapter 4)
- Recommend related supply side initiatives required to achieve energy efficiency (Chapter 5)
- Analyses barriers and recommend alternatives for the implementation of demand side measures (DSM) in the agricultural sector in UP (Chapter 6)
- Develop a pilot project profile for implementing DSM in UP (Chapter 7)

2. Background

1 The agricultural sector is the largest consumer of power in Uttar Pradesh accounting for 36 8% of total sales The industrial sector with 24.3% of sales is the second largest consumer. The agricultural sector, therefore, strongly influences power demand in the state Bulk of the sales to the agricultural sector are unmetered and based on flat rate tariff based on horse power of the irrigation pump motors Thus there is hardly any motivation on the part of the consumers to adopt energy conservation measures. It is thus, perhaps, of greatest interest to UPSEB to analyze the loads in agricultural sector and its impacts on the system load

3. Survey Results

2 During the survey of farmers, more than 75% of the pumpsets were of 5 hp capacity and the number of operation hours are estimated to 1600 hours per pumpset per year. As far as the preference on operation time of pumpsets is concerned, farmers were keen on day time. Average maintenance cost per pumpset per year varies between Rs 1500-2000 in Meerut, and from Rs 1500-2500 in Jaunpur.

3 *Feedback from mechanics* Smooth working, longer life and good performance during load fluctuations are the basic parameters considered by the mechanics while recommending any particular brand From the feedback it was clear that, there have been no special effort to promote efficient pumpsets Repairs except that are related to the pump/motor are generally done at the field. Mechanic either visits on goodwill or takes conveyance fee from the farmer. The average turnover per mechanic per year was Rs 30 940 (about 28 rewinding per year) and Rs 128 700 (about 99 rewinding per year) in Meerut and Jaunpur respectively.

4 *Feedback from retailers*: Though the shop owners are educated, they are not particular in promoting energy efficient pumpsets and components. However, they do not mind considering it seriously if their profit margin does not decrease.

4. Field testing and rectification of agricultural pumping systems

5 82% of the pumping systems had energy index more than 0.9 kWh/UIW The pumps with an energy index more than 0.9 kWh/UIW, need either maintenance or rectification. The average energy index before rectification was 1.068 (ranging from 0 66 to 1 28). The average energy index was brought down to 0.789 (an improvement of 20 6%) with suitable rectification. A combination of the following rectification were conducted in each of the pumpsets They are, replacement of GI pipes with PVC, foot-valve, check valves, belt bearings of motor, bush of pump, electrical winding of motor, reducing sharp bends etc , and maintenance, such as greasing of the mechanical component The average component and material cost per pumpset was about Rs 2030 per year (3 pumpsets with minor modification and seven with major). However, minor rectification would be about Rs 660 and major, Rs 2620 per year per pumpset

6 *Implications of the intervention of rectification.* The average energy saving for the same discharge per HP of installed capacity thus would be about 299 kWh per year (energy consumption was reduced to 1080 kWh from 1379 per year per HP), a reduction of about 22% In other words, there has been an enhancement of discharge due to rectification by about 21% (the average discharge increased from 7 44 to 8 68 cubic meter per HP per hour)

7 *Implications at district level* , There are 50,852 and 24 127 PTWs in Meerut and Jaunpur districts respectively If the rectification measures as conducted in the above study are undertaken (7 3 proportion of major and minor rectification), the pumpset operating hours can be reduced to 1371 hours from the present 1600 hours per year for the same discharge or if continued to work for 1600 hour would result in irrigation of an additional land of 86 784 ha

8 *Post rectification details*, It is inferred here that the deterioration in efficiency of pumpset with time is non linear and may happen faster with due course of time Thus there is a need to establish the trend of deterioration more systematically to arrive at a conclusion regarding re-rectification

5. Load Shape Analysis

9 In the Load Shape analysis, it is observed that in the daily loading cycle, UPSEB system experiences two peaks, one in the morning lasting for 2 to 4 hours and the other in the evening lasting about 2 to 4 hours It is also observed that the morning peak is followed by the valley in the subsequent hours Since the agricultural irrigation loads forms the predominant component of the morning peak hours loads, UPSEB should try to shift part of the agricultural loads from morning peak hours to the following spread over the day (except evening peak hours) This would result in substantial savings in fuel costs because of the reduction in the morning peaks hour energy losses due to peak chopping Table E 1 below shows the capacity savings and annual energy savings due to shifting the agricultural loads from the morning peak to the off-peak hours.

Table E.1: Energy Savings from Load Management

With restricted loads	Capacity saving due to reduction in morning peak (MW)[1]	Annual energy saving (million Units) due to reduction in peak hour losses	Resultant annual saving in fuel costs(Savings in Rs Millions)
Summer	88 15 MW	15 86	8 409
Winter	153 43 MW	27 62	14 638
Monsoon	-	-	-
With unrestricted loads			
Summer	174 4 MW	15 70	8 32
Winter	243 03 MW	21 87	11 59
Monsoon	-	-	-

6. Supply Side initiatives for Energy Conservation

10 The method suggested in the present report for remote controlling of agricultural load has attempted to overcome the draw-backs of the present methods of either switching off the power supply of the 11 kV feeder or extending 2 phase supply to the rural consumers being followed by UPSEB. By installation of remote switching devices on the L T. side of the DTs (supplying rural loads), it has been ensured that all

[1] Vide appendix 5 of the report

the rural L T feeders are not starved of supply at the same time, and a group of villages would get supply at fixed hours as per rostering schedule. Secondly, the scheme provides for segregation of irrigation pump loads from the domestic, commercial and LT industrial loads so that even when pumps are switched off, other loads would continue to get supply By dividing the agricultural loads on each feeder to half, this scheme will reduce the peak hour losses to half and releases extra generation and distribution capacities.

7. Implementation of DSM: Key issues and options.

11. Chapter 6 outlines the scope for implementation of DSM on a commercial scale in the agricultural sector of UP. Energy savings of around 18% of current consumption in electric pumps, used for lifting water, can be achieved through retrofitting and scheduled maintenance. Energy savings can be commercially extracted by restricting the supply of energy to pumps in a way that farmers continue to get the same volume of water as at present. The consequent energy savings can be sold to UPSEB or any other consumer Table E.2 lists the benefits of implementing DSM in Meerut and all UP under the best and worst case scenario. The benefits can be viewed in terms of employment generated by a project to implement DSM, deferment of capital cost on account of avoided new generation and related capacity due to the realease of energy through conservation and the lower cost at which conserved energy is available as compared to the additional generated energy The best case scenario assumes the sale of saved energy at Rs 2 25 per kWh and the need to rewind motors only once in five years The worst case scenario assumes the sale of saved energy at Rs 1 8 per kWh and the need to rewind motors once in two years

Table E. 2: Benefits from DSM

Benefit	Unit	Meerut-Best Case	Meerut-Worst Case	UP - Best Case	UP-Worst Case
Employment	Nos	398	342	5532	4756
Capital cost of deferred new generation capacity	Rs million	639	629	3555	3419
Reduction in cost of power* made available	Rs/kWh	0 45	0 76	0 45	0 76

* Reduction in cost of power calculated assuming cost of conventional power as Rs 1 9 to 2 5 per kWh

12 It is not however to establish the economic desirability of implementing DSM which are well known Ideally DSM measures are prime candidates for public intervention since the bulk of the benefits from conservation are positive externalities or the avoidance of negative externalities However public intervention in India in this area does not have a very good record Consequently the reliance on private initiative

becomes imperative for early and effective action Private initiative flourishes only where returns to capital invested on a risk weighted basis are comparable with the opportunity cost Chapter 6 establishes that the returns on equity invested in DSM by an Energy Servicing Company (ESCO) gets an IRR on equity of between 26% to 188% depending on the assumptions used for defining key variables like the rate of motor failure and the rate at which saved power would be sold by the ESCO The payback period on equity invested varies from 14 to 37 months Table E.3 below lists the returns on equity estimated to be available to an investor

Table E.3: Comparative IRR on Equity Invested in DSM (Debt Equity Ratio 50 50)

Power sale rate/Motor rewinding frequency	Bi-annual	Once in 5 yrs	Reference
Rs 1 80 per kWh	46%	88%	Appendix 6 B/D
Rs 2 25 per kWh	114%	188%	Appendix 6 C/E
Reference	Appendix 6 B/C	Appendix D/E	

These financial indicators are commercially acceptable for investors Consequently there is a commercial opportunity waiting to be utilised through the implementing of DSM measures in the agricultural sector of UP

13 The key barriers which would hinder implementation is the new nature of the project, the intangible nature of the services provided and the output, the non asset based service oriented scope of the exercise and the absence of the price motive in implementing DSM in agriculture since power is supplied at highly subsidised flat rates Chapter 6 discusses these barriers and the marketing strategy needed to be adopted to overcome these barriers

14 One major problem in commercially extracting energy savings is that energy consumption is not metered in agriculture. Physical controls on consumption therefore become necessary to extract energy savings Chapter 5 describes the most cost optimum method for restricting energy supply to agriculture The Remote Controlled Load Management System (LMS) proposed in this chapter has the added advantage that it saves an additional 5% of the energy consumption in the distribution system through reduction of peak demand However the LMS is a very capital intensive scheme on a stand alone basis The annualised cost of this scheme on the basis of the direct benefits accruing from it in terms of saved energy comes to around Rs 6 75 per kWh which goes up to Rs 13 24 per kWh if the costs of segregating agricultural load are included This compare unfavorably with an annualised cost of around Rs 1 55 per kWh for the DSM component Table E 4 below indicates the comparative annualised cost of the DSM and LMS components

Table E.4: Comparative Annualised Costs

	DSM- Worst Case	*DSM- Best Case*	*LMS- I*	*LMS-II*	*IS of DSM&LMS-I*
Annual cost Rs per kWh	1.79	1 55	13 24	6 75	2 67
Present Value of Costs @20% Rs1000	359898	310455	755906	385508	689377

Note - LMS-I includes the cost of segregation of agricultural load, LMS-II excludes this cost.

Avoidable System Financial Cost of Unmetered Supply

15. The prime motivation of including a LMS component in this study is to optimise the system of physical rationing of supply necessary in the absence of metered supply. The difference between the cost of saving power through a pure DSM project and an integrated project comprising both DSM and LMS, of around Rs 1.12 per kWh (Rs2 67 less Rs 1 55) can therefore be viewed as the avoidable system cost of un metered supply. Similarly the direct incremental investment of around Rs 375 million (Rs 689 million is the cost of an integrated project less Rs 310 million being the cost of implementing a pure DSM project) on account of implementing an integrated, as compared to a pure DSM project can be viewed as the avoidable system investment outlay necessitated by un metered supply to the agricultural sector The real annualised costs and incremental investment outlays would be much higher if the related investments needed to be made by UPSEB in load segregation of around Rs 353 million are also accounted for in the project. Chapter 7 provides a detailed analysis

Avoidable System Financial Cost of Peak Demand

16 Similarly the financial data generated in this study can be used to estimate the system cost of not using price signals to manage demand Rationing is an inefficient instrument for managing demand and hence an inferior option s compared to price incentives However the system of rationing supply suggested in this project is superior to the existing system since it reduces the peak load and hence distribution losses It is undoubtedly a high cost instrument with an annualised cost of Rs 13 24 (including the cost of segregating agricultural load) However it is still cheaper than the alternative of adding new peaking power capacity which would have an estimated cost of Rs 17 24 Chapter 7 provides a detailed explanation.

17 Appendix 6 F provides a stakeholder analysis for the implementation of DSM in agriculture While trained professional stand to gain through the creation of 5500

technical jobs all across UP the main losers are UPSEB staff which today are in a 'rationing mode' but would need to operate in a buyers market if the demand supply gap is breached Also likely to lose are those farmers who are able today, through political power, to extract a higher than the average share of the supply of power The gains to society have not been quantified but exist in intangible environmental benefits and in the release of additional power at competitive rates without additional capacity installation

8. Pilot Project Design

18 Chapter 7 outlines a pilot project for implementation in UP. The project would establish a commercial organisation with the objective of rectifying and maintaining the agricultural pumps in one district of UP The project implementor would also install and maintain the remote control load management system Some related investments regarding the segregation of agricultural load would need to be done by UPSEB The cost of segregation is estimated at Rs 353 million and is not included in the costs of the project. The project envisages that 50,852 pumps would be rectified and maintained over a 78 month project period at a capital investment of Rs 137 million An additional investment of Rs 160 million would be made in rationalising the supply system to reduce distribution losses by reducing the peak demand Maintenance costs are heavy and account for around 60% of the present value of total costs An estimated 60 3 gWh of energy would be saved through a reduction in the supply of power to these pumps and an additional 17.1 gWh through the reduction of distribution losses The saved energy would be sold to other customers at a minimum rate of Rs 2 25 per kWh The IRR on total project cost comes to 31% at a discount rate of 20% per annum The related payback period for recovering the entire project cost is 55 months out of a total project period (including implementation time) of 78 months Table E 5 below lists the financial returns of the project under different assumptions Alternatives 1 & 2 have been developed assuming that saved power will be sold at Rs 1 8 per kWh and scenario 3 at a rate of Rs 2 25 per kWh.

Table E.5: Comparison of financial returns for Integrated Scheme

Alternative Scenarios	*IRR*	*Payback (Months)*	*NPV Rs 1000*	*Reference*
1 Including avoided capital cost	156%	15	817763	Appendix 7 J
2 Excluding avoided capital cost- Worst Case	9%	86	-48899	Appendix 7 K
3 Excluding avoided capital cost- Best Case	31%	55	54947	Appendix 7.L

If UPSEB is envisaged as the project implementor then it is reasonable to include the avoided cost of deferred investment to add 38 MW of peak capacity estimated at Rs 1899 million Under these assumptions the IRR on full project cost is a very attractive

156% If only the returns from saved energy are considered the project becomes non investment grade since the IRR falls below even the rate of discount of 20% per annum. However if we assume that saved power would be sold at Rs 2 25 per kWh (the current rate for sale to HT industrial consumers is Rs 2.47 per kWh) then even without including the benefit of avoided cost to UPSEB the project is viable with an IRR on full project cost of 31% and a payback of full project costs in 55 months. These are attractive rates of return Consequently the project is self supporting and requires no subsidies.

19. The project envisages a conservative debt equity structure of 59 41 The availability of commercial debt is likely to be restricted due to the non asset backed nature of the investments and the service orientation of the project. The service orientation and the rural base of the customers requires an entrepreneur well versed in local customs and attitudes. Familiarity with local institutions and the ability to mobilise social opinion will be important prerequisites. Consequently the potential entrepreneurs would most likely be those already operating in the region in trade or manufacture of pumps, agricultural machinery, motors, transformers, electronic goods or agro based products like sugar

20 Chapter 7 suggests four separate organisational structures but surmises that possibly the most efficient may be either a energy servicing company (ESCO) or a private utility which would take over the entire distribution function of the project area

21 However it may be difficult for local entrepreneurs who are ideally situated to be ESCOs to raise Rs 121 million as equity for the project Consequently Chapter 7 suggests several alternatives both for enhancing the equity pool through cooperatives and the support of specialised financial institutions as well as means of leveraging the equity adequately

22 Table E 6 below gives the easily quantifiable gains from an integrated DSM and LMS project to the primary stake holders The estimation uses data from the IRR analysis and annual cost analysis given in more detail in Chapter 7

Table E.6: Gains to stake holders from a integrated DSM & LMS project

Stake holder	*Present Value of Gains in Rs million*
Farmers	259
UPSEB	1546
Project Implementor	92

The maximum gain is to UPSEB which saves Rs 1546 million in avoided capital expenditure in new generation and related distribution capacity even after spending Rs 353 million on segregation of agricultural load The gains to farmers are in terms of

the present value of avoided maintenance expenditure over the six years of the project period (assuming annual maintenance expenditure on pumps at Rs 1500 inflated by 10% per year over six years and present valued at a discount rate of 20%) The gains to the project implementor are the profits before tax and depreciation, accruing to him over the project period discounted at 20% per annum

9. Conclusions

23 The commercial extraction of energy efficiency gains is possible in UP. The gains are most likely to be most effectively extracted through private intervention in the form of a Energy Servicing Company specially mandated by UPSEB for this purpose or a privatised utility Substantial gains accrue to UPSEB in terms of avoided capacity UPSEB would need to spend a part of this saving on segregation of the agricultural load to facilitate implementation of the project The availability of finances for such a project would need the evolution of innovative financial instruments Government financial institutions would need to reinterpret restrictive investment rules, formulated for asset backed financing, in terms of the special requirements of this service oriented largely non asset based project. The non financial barriers, legal, administrative and institutional constraints are also formidable Tariff reform, aimed at the establishment of market based prices for power, would provide the much needed incentive , absent today, for inducing consumers to adopt energy conservation Since this incentive is absent, energy conservation requires the administrative, though not necessarily the financial, support of the Government of UP, UPSEB and Multilateral and Bilateral donors The pilot project design suggested in this report needs to be tested through a fuller and open discussion with representative stake holders from UP We would recommend that the proposals be discussed at a workshop, as a prelude to implementation of the pilot project design

CHAPTER 1

Introduction

The agricultural sector in Uttar-Pradesh accounts to almost 36.8% of the total energy consumed in the state. Substantial peak demand is imposed on the system by over 20,000 state deep-tubewells and 700,000 private tubewells in the state While the demand for electricity for irrigation is growing, the part with regards to the supply of electricity is not very encouraging as there has been continuing shortage The agricultural sector is the largest consumer of power in the state followed by the industrial sector with 24.3% of sales The agricultural sector, therefore, strongly influences power demand in the state. The agricultural sector receives power at both high and low voltage from transmission and distribution lines The load on these lines is largely for agricultural pumps, though some rural domestic and commercial loads would also be served by these feeders The agricultural sector is largely unmetered and pays a fixed tariff based on the connected load It is thus, perhaps, of greatest interest to UPSEB to understand loads in this sector and estimate their impacts on the system load The tariff for electricity sales of UPSEB to the various consumer sectors is so structured that the rates for agricultural sector supply are well below the Board's cost of production and Industrial sector tariff provides considerable subsidy to the agriculture sector The loads and the tariff structures in the agricultural sector in Uttar-Pradesh prompts the introduction of Demand Side Management (DSM) so as to beget the desired change in Uttar Pradesh State Electricity Board (UPSEB) load structure

The study aims at developing the Demand Side Management investment strategy and business design for the agricultural sector in UP. The two investment components of the study are.

- Rehabilitation and modernization of private agricultural pumpsets, and
- Control of agricultural loads through direct control of utility equipment

While developing the investment strategy for the agricultural sector, the study is looking the objectives at the three levels

(1) *Sector level* This includes the improvement in the power supply to the agricultural sector, revenue enhancement and overall sector productivity This also includes the analysis of the role of ESCO's, private investors, in mobilizing necessary investments in the improvement in the sector, and the technical and institutional barriers.

(2) *System Level* This level states the problems associated with the current practices of load rostering in the agricultural sector for peak load management. The scope of Remote Controlled Load Management through various techniques is also assessed at the system level

(3) *End Use Level* Under the end use, the performance of the agricultural pumps and motors are studied to evaluate the cost effectiveness of the rectification/modernization of pumpsets.

An extensive study covering the above aspects was undertaken by TERI with a view to developing on DSM strategy in the agricultural sector in U.P and suggest project investment components comprising: (a) renovation and modernization of agricultural pumpsets and (b) rural load management through direct control of client's equipment The study report focusses on DSM project investment strategies and has attempted to identify the available options for realizing the objectives. On the basis of the results of the studies, the report suggests an implementation strategy based on the policy instruments currently available to the U P Government. It may be mentioned here that the suggestions made are compatible with the recent liberalization policy of the Central Government in the field of power supply industry in India both in the field of generation and distribution of electricity

Survey of Pump Users, Mechanics and Vendors

Summary of Methodology

The study was carried out in two districts in the state of Uttar Pradesh (a list of villages are given in Appendix 2). The detailed methodology of the study included,

1 Selection of study area, selection of 33 kV substation and 11 kV feeders
2 Secondary data collection
3 Primary survey
   A Survey of agriculture pumpsets based on feedback
   B Feedback from Mechanics
   C Feedback from Retailers
   D Rectification of agriculture pumpsets
   E Post rectification measurements

Further details of the survey methodology are provided in appendix 3B

Analysis of Survey

There are 62 districts in the state of Uttar Pradesh About 13 commissaries' have been formed consisting of three to seven districts each District Meerut comes under Meerut commissary, where there are five districts in total District Jaunpur, comes under Varanasi commissary where there are six districts

Profile of Meerut district

There are about 1030 villages in total in Meerut district of which 920 villages are inhabited. All the villages are electrified according CEA definition (Central Electrical Authority - CEA definition - A village is said to electrified if an electrical line is passing at a distance of 3 kM from the village), however, only 799 villages (78%) are electrified with the LT mains (which means a Low Tension line actually passing through the village) Density of private tubewells: There are about 47 802 private tubewells in Meerut district which is the largest number in any district in Uttar Pradesh This would mean an average of about 45 per village (considering total number of villages) and about 60 per village (if only villages with LT mains are considered

Profile of Sardhana substation

Sardhana substation was selected after having discussions with the officials of the UPSEB The total load on this substation is 8 MW The electricity supply for this substation comes from a 132 kV Mandhiai. Of the 8 MW of power 0.8 MW is used for domestic, 5.5 MW for agriculture, 1 7 MW for industries Sardhana was selected for our study since this has large

agricultural load and also was suggested by the UPSEB officials

A questionnaire was developed which was administered to sample farmers randomly in the selected sub-station, Sardhana Effort was made to visit and fill up the questionnaires at the farm sites so as to ensure reliable feedback

General information

Survey sample Survey was conducted in 129 households covering 142 pumpsets. 136 of the pumps surveyed were electrical and 6 diesel engine pumpsets. All the electrical pumpsets were of centrifugal type. The villages covered for the study are given in the Appendix 2

Educational status

About 78% of the farmers interviewed by us were literate. However, from the interview it was very clear that there was no awareness regarding performance of pumpsets and energy conservation measures. The details of the educational status are provided in the table 2 1

Table: 2.1 Educational status of farmers interviewed in study area in Meerut district

S No	Status	Percentage % (Number)
1	Illiterate	23 (29)
2	Primary	23 (30)
3	Middle	14 (18)
4	High	26 (33)
5	College level	15 (19)
	Total literate	78 (100)
	Total	100% (129)

Land holdings

Categories have been made in accordance with the All India report on Agricultural Census as given in the table 2 2 The table 2 2 provides the details of the land ownership More than 85% of the farmers belong to semi-medium, and medium farmer (farmers having land holding of 5 to 25 acres) category

Table: 2.2 Land holdings of the surveyed households in the study area in Meerut district

Category	No of farmers	Percentage (%)
Marginal farmers (below 2 5 acres)	1	1
Small farmers (2 5-5 acres)	2	2
Semi-medium farmers (5-10 acres)	31	24
Medium farmers (10-25 acres)	80	61
Large farmers (25 acres and above)	15	12
Total	129	100

Note The land categorization has been taken in accordance with "All India Report on Agricultural Census 1980-81"

Details of tubewell/motor/pumpset/engine

The pumpsets, diesel engine systems surveyed during the study are categorized based on their capacities and the details are presented in the table 2 3. It can be seen that most of the pumpsets (about 75%) are of 5 hp capacity and population of pumps less than 5 hp is negligible The details of diesel engine pumpsets distribution are also given in the table 2 3

Delivery and suction pipes The pipe selection was based on the depth of water table, capacity of pumpsets and also what has been in use commonly in the surroundings. The delivery pipes were of four different sizes They are 3, 4, 5, and 6 inches in diameter, however, more than 95% of them were of 4 inch diameter Suction pipes were of three sizes, 4, 5 and 6 inches, in diameter About 70% of them are of 4 inch, 24% are 5 inch and the rest 6 inches in diameter. The details in terms of numbers are provided in the table 2 4

Table 2 3 Pumpset capacities and types in the surveyed households in the study area in Meerut district

Type/ Capacity of	Numbers	Percentage (%)
Electric pumpsets		
2 5 hp	1	1
5 hp	102	72
7 5 hp	30	21
10 hp	3	02
Sub total -1	136	96
Diesel engine pumpset		
7 5 hp	4	3
10 hp	1	<1
Tractor	1	<1
Sub total -2	6	<5
Total	142	100

Table 2 4 Size of the pipes used in agricultural pumping systems

Delivery pipes (inches)	No of
4	129
5	8
6	3
3	2
Total	142
Suction pipes (inches)	
4	99
5	33
6	10
Total	142

Others assets Feedback on assets owned by the households was noted down which was thought to be an indicator to the wealthiness of the farmer. In addition, this also provides an idea about the assets using electrical energy, thus load on the grid The assets using electricity provides an idea about domestic load in the study area

The feedback was compiled and are presented in the table 2.5. Most (93%) of the households have sheds for their tubewells for mainly two reasons. (I) safety from theft, (ii) protection from rains etc. As can be seen from the table, there are many mechanized implements in use for agriculture in the study area. Almost 50% of the households own tractors Animal power for ploughing etc. has been completely replaced in this area

Table: 2.5 Assets owned by the surveyed households (129) in the study area in Meerut district

Assets	Number of farmers owning the asset	Capacity (KW)	Total load (KW)	Percentage (%)
Tubewell shed	120	-	-	93
Car/Jeep	6	-	-	5
Tractor	57	-	-	44
Motorcycle\scoot	62	-	-	48
Livestock	115	-	-	89
Assets using electrical energy				
Pumpset	136	3 7	503 2	105
Thresher	45	1 11	49 95	34
Total connected load for agriculture = 553 kW				
T V	101	0 09	9 09	78
Fan	112	0 22	24 64	87
Cooler	44	0 185	8 14	34
Refrigerator	19	0 058	1 102	15
Electric iron	38	1 0	38 0	30
Cooking heater	33	1 5	49 5	26
Room heater	Nil	1 0	nil	nil
Bathing heater	nil	2 0	nil	nil
Lighting load			46 44	
Total domestic load - 177 kW				
Total load - 730 kW				

Note The average lighting load per household is taken to be about 160 watts

Cropping pattern

The primary crop in this region is sugarcane The details of other crops grown in different season are given in table 2 6

Table 2 6 Crops grown season-wise in the study area in Meerut district

Season	Crops grown
Rabi	Sugarcane, wheat fodder, vegetable
Kharif	Sugarcane, vegetable rice
Summer	Sugarcane, fodder

Information about pumpset

The questionnaire covered a number of points related to agricultural pumpsets The feedback collected from the responses in the field were compiled and explained in brief in the following sections

Make of pumpset

As can be seen from the table 2 7 a large number of (almost 50%) farmers have locally manufactured pumpsets Ten different brands other than local are in use. Among other than local Crompton, Jyoti, A I, GEC and Kirloskar are more in number

Table 2.7 Different make of pumpsets used in the study area in Meerut district

SN	Make of pumpset	Number	Percentage (%)
1	Local	61	44.9
2	Crompton	20	14.7
3	Jyoti	19	14.0
4	A I	14	10.3
5	GEC	9	6.6
6	Kirloskar	7	5.1
7	Texmo	2	1.5
8	Orient	1	0.7
9	Oswal	1	0.7
10	BSE	1	0.7
11	ECE	1	0.7
	Total	136	100

Reasons for buying particular brand of pumpset

Three reasons have been identified as influencing factors in buying a particular brand pumpset, I) experienced farmers in the neighborhood, ii) local mechanics and iii) the cost. Only a small fraction of farmers seem to have followed advise of local mechanics However, a small fraction of farmers could not respond properly to this question

Table 2 8 Influence on buying pumpsets

Reason for buying	No of farmers	Percentage (%)
Suggestion from local mechanic	8	6
Could not respond properly	12	8
Price (cheap)	51	38
Influence by fellow farmers	65	48
Total	136	100

Other things

- Most of the farmers were not aware of the expected life of the pumpset
- Pumpsets were purchased on cash basis
- Farmers were not aware about the capacitor and also the usage.

Operation hours

The operation hours largely depend upon the seasons From the feedback, it was clear that, the hours of operation per day was 6 hours in rabi, 4 hours in kharif, and about 10 hours in summer. Based on the feedback, and common practice in this area, pumpsets are run for about 90 days in rabi, 30 days in kharif, 90 days in summers. Thus an average pumpset runs for about 1600 hours per year

Preference of payment

At present a flat rate system of Rs 50 per horse power is in practice Largely, farmers preferred flat rate system However, small number of them preferred pro-rata (price based upon meter) Based on the feedback, about 16% (21) farmers preferred Pro-rata

Preference of time of operation of pumpset

Most of the farmers preferred power during day time to energize their pumpsets This preference is largely because, it is convenient and also safe

Maintenance cost

The annual maintenance cost varied between Rs 1500-2000 per year. The cost of maintenance (including cost of components) of various components are given in table 2 9

Table 2.9 Repair and maintenance cost of components of agriculture pumping system

S No	Components	Cost (in Rs)
1	Winding	800 - 1200
2	Bearing	150 - 300
3	Bush	50 150
4	Shaft	80 130 per ft
5	Fan	100 - 200
6	Greasing	20 - 50
7	Belt (in case of	10 25 per feet
8	Check valve	50 150
9	Foot valve	400 - 700
10	Coupling	200 - 300

Profile of Jaunpur district

There are about 3397 villages in total in Jaunpur district of which 3245 villages are inhabited. Though 88% (2995) of the villages are electrified according to CEA definition, only 30% (959) of the villages are electrified with LT mains

Density of tubewells

There are a total number of about 24 127 private tubewells in the district. This means an average of about 25 pumpsets per village in the electrified villages with LT mains. However, if an average is taken for the total number of villages it would be about seven pumpsets per village

General information

Survey was conducted in about 110 households covering 113 pumpsets 99 of them were electrical, 8 diesel engine and 3 of them are both The list of villages surveyed are given in the Appendix 2

Educational status

About 64% of the farmers interviewed by us were literate However, from the interview it was clear that, there was no awareness regarding performance of pumpsets and energy conservation measures The details regarding the educational status of the households surveyed are provided in the table 2 10

Table. 2.10 Educational status of farmers interviewed in the study area in district Jaunpur

Status	Percentage (Number)
Literate	
Primary	16 % (18)
Middle	16 % (18)
High	18 % (20)
College Level	8 % (8)
Sub - total	**58 % (64)**
Illiterate	**42 % (46)**
Total	100 % (110)

Land holdings

The details of the land holdings are provided in the table 2 11. Majority (64%) of the farmers fall under small and marginal farmers category. 94% of the farmers have less than 10 acres of land The population of large farmers is nil and that of medium farmers is only marginal

Table: 2.11 Land holdings of surveyed households in the study area (Jaunpur district)

Category	No of farmers	Percentage (%)
Marginal Farmer (below 2 5 acres)	31	28
Small Farmer (2 5 - 5 acres)	41	36
Semi-Medium (5-10 acres)	33	30
Medium Farmers (10-25 acres)	6	6
Large Farmers (25 acres and above)	nil	nil
Total	110	100

Note Land holding categorization has been taken in accordance with "All India Report on Agriculture census 1980-81"

Details of tubewell/motor/pumpset/engine

Electrical pumps of 3, 5, 7 5, 8 and 10 hp were found in this region Most (77%) of the electrical pumps were of 5 horse power capacity whereas pumps of higher than 10 hp was nil and less than 5 hp was just one.

Table 2 12 Pumpset Capacities in the surveyed households in the study area (Jaunpur district)

Type/Capacity	Number	Percentage (%)
Electric pumpsets		
3 hp	8	7
5 hp	87	77
7 5 hp	7	6
Sub - total	102	90
Diesel engine pumpset		
8 HP	9	8
10 HP	2	2
Sub - total	11	10
Total	113	100

Other assets

Feedback on assets owned by the households was noted down which is an indicator to the wealthiness of the farmer In addition, this also provides an idea about the usage of electrical energy The assets using electricity provides an idea about domestic load in the study area. The feedback was compiled and are presented in the table 2 13

Table 2 13 Assets owned by the surveyed households (110) in the study area (Jaunpur district)

Assets	No of Farmers who	Percentage (%)	Capacity (kW)	Total load (kW)
Storage shed	106	96		4
Cattle shed	103	94		7
Farm building	34	31		76
Tube well shed	108	98		2
Car/jeep	9	8		101
Tractor	14	13		96
Live stock	108	98		
Motor	30	27		80
Assets consuming electrical energy				
Pumpset (average 5	102	93	3 7	377 4
Thresher	104	95	1 11	115 44
Total connected agriculture load for = 493				
Television	63	57	0 09	5 67
Fans	66	60	0 22	14 52
Lighting load				20 19
Total domestic load			39 99	
Total			534	

Note The average lighting load is taken to be about 180 watts per household

Connected load

The total connected load of 110 households was about 533 kW The share of agriculture loading is about 93% and the domestic loading accounts to only 7%

Cropping Pattern

The crops grown in this area are as given in the table below:

Season	Crop Grown
Rabi	Mustard, Wheat, Pea, Pigeon Pea, Vegetable, Sugarcane
Kharif	Paddy, Maze
Summer	Fodder, Vegetable

Information about pumpset

The feedback collected from the responses in the field are compiled and explained in brief in the following sections.

Make of the pumpset

Large number of farmers have purchased reputed brands such as GEC and Crompton Greaves These two brands account for over 65% of the pumpsets surveyed in this area The following table 2 14 provides further details on number and percentage of each type

Table: 2 14 Different makes of pumpsets used in the study area in Jaunpur district

SN	Make	Number	Percentage (%)
1	GEC	41	40
2	Crompton Greaves	28	27
3	HMC	7	7
4	Orient	7	7
5	Siemens	4	4
6	AI	3	3
7	ASIA	2	2
8	ABB	2	2
9	PMS	1	1
10	BBC	1	1
11	Motors & Machine Ltd	1	1
12	Bajaj	1	1
13	MEC	1	1
14	BBI	1	1
15	IEC	1	1
16	ECE	1	1
	Total	102	100

Buying Pattern of Pumpsets

Majority of the farmers (86%) bought pumpsets first hand and the rest bought it second hand. As can be seen from the table 2.15, selection was mostly influenced by fellow farmers and substantial number of people were not even aware of the reason for buying that particular brand pumpset However, about 18% of the people took the advise from the mechanics in selecting a pumpset. The bank influence was to the extent of about 13%.

Table 2 15 Influence on selection of a particular brand of pumpset

S No	Reason	Number	Percentage (%)
1	Suggested by fellow farmers	38	37
2	Don't know	20	19
3	Suggested by mechanic	18	18
4	Suggested by Bank Officials	14	14
5	Cheap	12	12
	Total	102	100

Mode of Payment

A substantial number (60%) of surveyed farmers availed loan facility in the study area The sources of loans and the number of farmers who availed it, are provided in the table 2 16

Table. 2 16 Source of loan for purchase of agriculture pumpset

Source of loan	No of farmers
Land Development Bank (interest rate @ 12, 13, & 14%)	25
Union Bank	35
Block	1
Total	61

Other things

- They are not aware of the expected life of the pumpsets
- They generally get their pumpset repaired through site mechanics.
- Usage of capacitor was not in practice and was in fact, unknown to the farmers..

Preference of payment

At present a flat rate system of Rs 50 per horse power is in practice Almost 50% of the farmers were ready to pay metered billing, provided, assured power supply during convenient hours (preferably during the day time) About 40% of the farmers were ready to pay an additional price if extra power was made available to them.

Maintenance cost

The annual maintenance cost varied between Rs 1500 to 2500 per pumping set The details of the maintenance cost are almost similar to the one provided in the earlier section for Meerut district

Feedback from the mechanics

As a part of the study, it was decided to interview a few mechanics in order to get an idea about repair and maintenance related to the pumpsets and also cross examining the annual maintenance cost from the feedback from the farmers A questionnaire was prepared to get information from the mechanics. Analysis is made and presented in the following sections for both the study areas The differences are mentioned if any.

Details of the survey

Meerut study area Five Mechanics were interviewed in Sardhana of Meerut District None of the mechanics had technical qualification However, all the mechanics were literate from middle school to college level They also had farming as their secondary occupation. All these mechanics have their own shop. However, they also make field visits whenever there is a need. They were hesitant to provide information regarding their monthly income

Jaunpur study area Four mechanics were covered at Jalalpur. Three of them were literate and the maximum education was up to high school

Opinion of mechanics regarding people's preference of buying a particular brand pumpset It is felt that people are more influenced by fellow farmers than mechanics. Mostly people prefer to buy pumpsets (according to mechanics) like AI, Kirloskar, GEC, Jyoti, Lubi, Crompton etc However, field survey revealed that local brands are more common in Meerut study area among the farmers At Jaunpur, known brands like GEC, Crompton, Siemens, and Orient are more common

Mechanic's advise regarding selection of pumpset

Different mechanics had different opinions as regards to suggesting brands of pumpsets The main brands as suggested by most of the mechanics are, Crompton and GEC. They are of the opinion that these work smoothly, have longer lives, and provide good performance (performs better even when there are greater fluctuations of electricity).

At Jaunpur, mechanics mainly advise the following brands;

(I) GEC,

(ii) Crompton and

(iii) Siemens.

Reasons for the selection of brands (as seen from farmers point of view)

At Meerut It is interesting to note the following reasons for the selection of local brands: (I) local brands are much cheaper when compared to reputed brands, (ii) fear of theft of reputed brands is more than that of local brands It is interesting to note that some of the farmers who can afford to buy reputed pumpsets, hesitate to buy them, because of greater fear of theft of the reputed brands. We were told that a good number of people who had reputed pumpsets earlier and were stolen, have gone in for local brands They also feel that they can buy almost two such pumpsets in place of one reputed pumpset, thus guarding from greater effect of theft

At Jaunpur It is to be noted that a majority of people own reputed brands in this area. Also, there are less cases of theft when compared to Meerut The maintenance of the pumpsets seem to be better than at Meerut region

Promotional activities

It was observed that none of the representatives of the pump/motor manufacturers visit the mechanics. Thus, there is no special effort to promote efficient pumpsets.

Criteria for choice of mechanic by the farmer

This mainly depends on the experience of the mechanic, the quality of service he provides and also the time in which he completes the job.

Procurement of spare parts

Spare parts and accessories are procured from the market at Meerut, which is about 25 kilometers from Sardhana The transportation is generally by bus, however, sometimes tractors are also used as a mode of transport. They buy goods either on cash or in some cases on credit basis At Jalalpur, mechanics either go to Varanasi (50 kMs) or Jaunpur (25 kMs) to buy the spare parts. Buying system is same as mentioned above

Repair of the pumpsets at field

If there is a request to the mechanic to repair the pumpsets at site, such as repairs related to the electrical connections, the mechanic either bargains for the conveyance or visits on goodwill However, the pumpset has to be taken to the shop if the windings are burnt.

Quantum of repair work by mechanics and their earnings

An effort was made to know the number of units a mechanic would repair in an year was made by using questionnaire.

Meerut study area. Five mechanics were interviewed in Sardhana. However, only four of them answered to the questionnaire and the information is compiled in the table 2 17 The earnings in an year varied from Rs 21000 to 38400 and thus the average turnover per mechanic was about Rs. 30940 per year On an average it was found that about 28 winding are repaired by a mechanic

Table : 2.17 Number of units repaired (per year) and charges (agricultural pumping systems) at Sardhana (district Meerut)

Details of repair	Mechanic 1		Mechanic 2		Mechanic 3		Mechanic 4			
	No	Charges (Rs)	No	Charges (Rs)	No	Charges (Rs)	No	Charges	Total No	Charges
Winding	15	18750	36	36000	25	30000	36	25200	112	109950
Greasing	15	1500	36	720	125	4375	36	360	212	6955
Bearing	20	500	72	1440	60	2100	12	240	164	4280
Bushes	10	250	12	240	25	875	12	240	59	1605
Belts							24	480	24	480
Coupling							24	480	24	480
		21000		38400		37350		27000		123750

Jaunpur study area

Four mechanics were interviewed at Jalalpur. The turnover per mechanic ranged from Rs 98500 to 162500 and the average turnover was about 128700 which is much higher when compared to mechanics at Meerut Study area On an average it was found out that about 99 windings are repaired by a mechanic Further details are provided in the table 2 18

Table 2.18 Number of units repaired (per year) and charges (agricultural pumping systems) at Jalalpur (district Jaunpur)

Details of repair	Mechanic 1		Mechanic 2		Mechanic 3		Mechanic 4		Total No	Charges
	no	Charges (Rs)	No	Charges (Rs)	no	Charges (Rs)	no	Charges		
Winding	84	100800	96	144000	72	93600	144	158400	396	496800
Greasing	96	1920	120	3000	120	2400	96	1920	432	9240
Bearing	60	1200	60	1500	60	1200	48	960	228	4860
Bush	36	720	24	600	84	1260	60	1200	204	3780
Total	-	104640	-	149100	-	98460	-	162480		514680

Note Feedback was procured from the mechanics at Jalalpur in district Jaunpur

Feedback from the retailers

Units for selling Pumpsets are located at Meerut. We interviewed three retailers at Meerut and five at Jaunpur Brief details of the feedback are provided below.

Meerut All the three shop owners were graduates and one amongst them was a mechanical engineer. Business is their primary occupation Commonly sold pumpsets were, Kalsi, Crompton Greaves, Varuna, and Sara The submersible pumps sold are Chandra and KSB. According to the shop owners these brands are of good quality, cheaper, and durable. There is a system for after sales service Mechanics are either employed or paid on a commission basis to provide after sales services to the customers by the retailers Regarding the energy efficiency they didn't know much about it but they tell according to pump specification (from the manufacture pumps manual) They are ready to sell efficient pump if maximum cost margin would be provide to the retailers

Jaunpur Three retailers were interviewed at Jaunpur. All of them were graduates and business (agriculture pumpsets) is their primary occupation The pumpsets commonly sold were, GEC, Hindustan Machine Company (HMC), Crompton Greaves, ASIA, Zenith etc.

Conclusions

Following broad conclusions are made based on the survey conducted in two study areas. The study areas were, Sardhana substation in district Meerut and Jalalpur substation in Jaunpur district 129 farmers were covered during the survey in Meerut study area and 110 households covered in Jaunpur study area

Ownership of pumpsets

Most of the owners had substantial land holdings. More than 85% of the farmers belong to semi-medium (5-10 acres), and medium (10-25 acres), in Meerut study area and a majority (65%) fall under small and marginal category in Jaunpur study area

Agriculture and domestic loading in the surveyed households

Meerut study area was found to be more prosperous based on land and assets owned by them and also based on the energy consumption The average connected load per household in Meerut study area was 6 1 kW and was only 4.9 kW in Jaunpur study area. The total connected load in Meerut study area (129 households) was found to be about 730 kW of which 76% of the load contributed to agriculture (includes agriculture pumpsets and threshers) and 24% towards the domestic loading. The appliances among domestic loading includes, televisions, fans, coolers, refrigerators, electric iron, heaters for cooking. The total

connected load in Jaunpur study area (110 households) was 533 kW. The share of agricultural loading is about 93% and the domestic loading accounts to only 7%

Cropping pattern

Major crops grown differed in different study areas and also season-wise Following were some of the main crops at Meerut, season-wise - Sugarcane, wheat, fodder, vegetable in rabi; Sugarcane, vegetables, and rice in Kharif; Sugarcane and fodder in Summer. In Jaunpur study area, following were the crops; rabi - mustard, wheat, pea, pigeon pea, vegetable. sugarcane: kharif - paddy, maize, summer - fodder, vegetables

Awareness about rectification

Though many of the farmers were literate (78% in Meerut and 58% in Jaunpur), they were not aware of the performance of agricultural pumpset rectification measures to enhance the performance, use of capacitors etc

Make of pumpsets

It was observed that farmers in Meerut study area preferred more locally manufactured pumpsets than in Jaunpur. One of the reasons is being the scare of theft was more among the people at Meerut Makes of the pumpsets generally used in Meerut area are, local (>45%) and other known brands such as Crompton, Jyoti, AI, GEC, and Kirloskar In Jaunpur area, most of the pumpsets used are of well known brands such as, GEC, Crompton Greaves, HMC and Orient.

Reasons for buying particular brand

The following were found to be the reasons for buying a particular brand pumpset, (I) influence of fellow farmers, (ii) price (cheaper), suggestion from mechanics, (iii) suggestion from bank officials The fellow farmers opinion seem to have greater influence in both the study areas However, some of the farmers could not respond to this question properly. It was also found that most of the pumps were purchased first hand In specific, in Meerut study area, about 48% of the buying was influenced by fellow farmers, 38% by price. Only about 6%, bought pumpsets based on the mechanic's advise In Jaunpur study area, the split was, 38% by fellow farmers, advise by mechanic's 18%. suggestions by bank officials was 14% and about 12% were influenced by the price (cheap)

Use of agriculture pumpsets

The operation hours varied according to seasons. The feedback indicated that 6 hours in rabi, 4 hours in kharif, and 10 hours in summer was the use of agricultural pumpsets in the study

area. Thus on an average a pumpset is operated for about 210 days in an year. Keeping in mind the different operation hours in different seasons, the total number of operational hours per year is estimated to be about 1600 hours.

Capacity of agriculture pumpsets

In both the study areas, maximum number (over 75%) of pumpsets used were of 5 horsepower capacity

Preference of working hours

In both the study areas, people preferred electricity for agriculture during the day time. Some of the reasons given were, scare from animals and as well as human beings (because of enmity)

Maintenance costs

The average maintenance cost per pumpset per year was substantial in both the study areas. In Meerut, the average cost varied between Rs 1500 - 2000, whereas at Jaunpur it was between Rs 1500 - Rs 2500 In Meerut, major components that need to be repaired/replaced are, bearing, bush, shaft, windings and flap for the foot valve. The cost of winding being the highest of all the above mentioned components. In Jaunpur, major components that need to be repaired/replaced were, bearing, bush, belts, shaft of the pump, check valve, and winding. The higher cost in Jaunpur is due to higher water depths, location of pump installation (it is generally installed inside an open well at a depth of about 10 to 25 feet), masonry work involved, belt and pulley system etc

Earnings from pumpset repair by the mechanics

The average earnings of mechanics at Jaunpur seems to be higher than that in Meerut However, we observed that people at Meerut were more hesitant to provide an accurate picture of their earnings The survey of four mechanics at Meerut indicated an average turnover of about Rs 30 940 per mechanic and Rs 128 670 per mechanic in case of Jalalpur.

CHAPTER 3

Pump Rectifications

Centrifugal pumps can operate at 70% efficiency in field conditions, but they are actually found to work only between 30 to 50% efficiency. The operating efficiency of electric motors is between 70% to 75% as against 88% efficiency that can be expected The pumping system as whole covering the motor, the pump, the power transmission system between the two, the piping system, and the foot-valve can work at 60% efficiency level in the field conditions. But the studies have indicated a system efficiency of only 13 to 27%.

Common defects observed in the pumping systems

A number of field studies have been carried out to enumerate the defects in the existing pumping systems in different parts of the country. The important defects in the pumping systems found are as follows: (I) Use of high resistance foot valves and reflux valves, (ii) Use of undersized pipes in suction and delivery lines, (iii) Suction lift more than six meters, (iv) Unnecessary height of delivery pipe, (v) Use of sharp elbows instead of bends, (vi) Use of inefficient and non-matching pumps, (vii) Too long or slightly leaky or clogged suction line, (viii) Inadequate or excessive RPM of the pumps, (ix) Inefficient or oversized electric motors, and (x) Use of belt drive instead of monoset pumps

Scope for energy conservation

Based on a number of studies and demonstrations, conducted by many organizations, it was proved that rectification of pumpsets owned and operated by farmers , by substitution of the high friction G I/MS pipes by low friction PVC pipes and low resistance efficient foot-valve, about 30 to 35% of electrical energy can be saved. The rectification measures, however, can broadly be categorized into two, (a) reduction of the friction losses in the foot valve and the piping system, and (b) improving the efficiency of the pump, the prime mover, and the power transmission system.

A low level of operating efficiency means excessive consumption of energy, whether electricity, or diesel. To assess the scope for energy conservation, several field experiments have been carried out involving various types of rectification works. The improvements in efficiency and consequent saving in energy have been measured. The results are very encouraging.

Brief details of REC's pilot programme on rectification of pumpsets

Rural Electrification Corporation launched a pilot programme on pumpset rectification in six states, namely, Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Madhya Pradesh and Haryana The monitoring of a sample of the rectified pumpsets was undertaken by different agencies like National Productivity Council (NPC), Hyderabad, Institute of Cooperative Management, Ahmedabad, M/s Karnataka Energy Consultants, etc. The summary of the

results of this pilot programme are given in the table 3.1.

Table: 3.1 Monitoring results of REC's pilot programme for rectification of agricultural pumpsets

Details	A P	Tamıl	Karnatak	Gujar	M P	Harya	*U P
Number of pumpsets rectified ın pılot programme	2500	3125	3125	3125	3125	3757	10
No of pumpsets evaluated by ındependent monıtorıng agency	505	500	525	500	527	569	10
Evaluation results							
Energy Index (kWh/UIW)							
El before rectıfıcation	1.13	1 20	1 12	1 19	1 17		1 06
El after rectıficatıon	0 82	0.90	0 73	0.81	0 82		0 79
Savıng ın energy	0 31	0.30	0 39	0.38	0 35		0 22
Savıng %	27	25	35	32	30	24	20 57
Discharge							
Dıscharge before rectıfıcatıon (LPS)	9 70	NA	NA	NA	9 87		12 32
Dıscharge after rectıfıcatıon (LPS)	13 58	NA	NA	NA	15 54		14 59
Dıscharge enhancement (%)	41	NA	NA	59.3	57 50	25 04	20 76

Note * Results of TERI study on the rectıficatıon of a small number of pumpsets as a part of the present project ın U P

Problems identified for the dissemination of rectification measures

Various agencies monitoring the above evaluation have come out with a set of problems for the dissemination and the remedial measures that have to be taken up to popularize and adopt rectification measures for different states. Some of the common problems associated wıth rectıfication are as follows:

- Problems related to attitudinal and field related.
- No incentive or stake by the farmers to adopt conservation measures sınce the agricultural tariffs are very low.
- Farmers traditionally prefer rugged GI pipes to the light weight RPVC pipes, despite latter's proven low-frictional resistance.
- Farmers not easy with frequent changes ın motor-beds because of new pumpset system
- Non availability of components such as cast iron foot valve in sufficient numbers.

Some of the remedial measures provided by them were,

- Propagating greater awareness among farmers to explain long-term advantages of rectıfication measures
- Initially rectification of only foot-valve and suction pipe might be undertaken as ıt would not involve changes in the motor-bed.

- The SEB's should volunteer and demonstrate the efficiency of these programmes to the farmers in view of the large socio-economic benefits to the Board.
- To study worthiness of metal and non-metal foot-valves for agricultural pumpsets.
- Mandatory strictures by the SEBs to adopt frictionless foot valves and HDPE/URPVC pipes in place of GI pipes for electricity supply.
- Rectification projects on a larger scale to be undertaken by the SEBs, REC, and NABARD together.
- Proper size of pipes to be used.
- All those pumpsets whose annual energy consumption exceeds 2,000 units should be considered for rectification.
- In future only energy efficient pumpsets should be financed and electrical connections given.

However, there has not been much success in adopting these measures. In many a states, it has not been demonstrated in the pilot scale. Thus there is an urgent need to demonstrate the rectification measures and formulate strategies to effect the dissemination in large scale.

Need for rectification and its study in Uttar Pradesh

Uttar Pradesh, being the largest state in the country, with large agriculture land and the state having one of the highest number of pumping sets, has not reported any significant studies on conservation measures. It can be observed that there is a large potential for rectification work in the state because of the large number of pumpsets. In addition, it has been observed that the UPSEB is facing severe shortage for power supply.

Though rectification work on pilot scale has been conducted in some states and it has been established that about 25% of energy saving is possible, studies have failed to provide further details on how long the improvement made would sustain. Also, the studies do not clarify, the duration in which the deterioration (efficiency levels falling back) takes place and further investments that have to be made to retain those efficiencies are not available. It is also to be noted that, the efforts made in other states in pilot scale have not succeeded in taking it further. Keeping all these things in mind, the project was designed to come out with investment and business strategy based on the field level work in selected study area.

Details of the pumping systems in the study areas

Meerut. Mostly Belt and pulley arrangement are used in this area, Also, monoblock and coupling system are also in use. Both the pump and the motor are placed on the ground. Most of the pumps were of centrifugal type with 5 to 10 hp capacity and the pump is directly placed over the boring. The boring pipe was mostly of 3 to 6 inches in diameter.

Jaunpur: Belt and pulley arrangement is mostly used in this area and the pump is installed below the ground level inside the well itself. The well is about one to one and a half meter in diameter and a depth of about 10 to 30 feet after which there is a bore. All the pumps were of centrifugal type with 5 to 10 hp of capacity. The wells are generally lined using bricks Platforms are provided to mount the pumps.

Description of typical pumpsets in the study area

Mainly pumping systems use belt and pulley in Sardhana (Dist. Meerut) and Jalalpur (Dist. Jaunpur). Sometimes monoblock pumping systems without involving a belt are also used in this area. But there is a basic difference in the pumping system in Sardhana and Jalalpur, which are explained in the following subsections.

Pumping systems with belt and pulley arrangement in Sardhana

In this system, the transmission of motion occurs through the belt from the prime mover (motor) to the pump. The motors found in this region were mainly of 5 and 7.5 hp. The pump and motor both are placed above the ground level and the motor and the pump are either placed at the same level or, at an inclined position. The water level found in this region is about 15 to 45 ft. The pump is directly placed over the boring pipe or suction pipe itself. A foot- valve is used which is fixed to the suction pipe, placed below the pump at a depth of 5 to 10 ft. The diameter of the foot-valve is same as that of suction pipe. Sometimes, during the survey it was found out that suction pipe and foot-valve are not of the same diameter, a taper piece is used to join the suction pipe and foot-valve. The function of the foot-valve is to prevent the reverse flow of water otherwise priming is needed every time to lift the water. During the survey, it was found that farmers use high friction local brand foot-valves instead of using low friction foot-valve. Use of G.I is in common because of age old practice, which imparts very high friction during the suction of water. The motors surveyed were found mostly of Local in Sardhana study area.

Description of pumpsets in Jalalpur area

In Jalalpur, almost all the pumpsets have belt and pulley arrangement. Pump is placed deep inside an open well over a platform at a depth of about 15 to 25 ft. Water table in Jalalpur region is about 15 to 45 ft, whereas the boring depth ranges from 50 to 220 ft. Boring is about 2 to 4 inches in diameter whereas a suction pipe is hung inside the boring to lift water But to prevent the suction of air, Jute or cotton is stuffed around the pipe. The pump installed inside the well is driven by a motor, which is placed above the ground, through a long belt. The motor found during the survey were mainly of known makes such as Crompton Greaves, GEC, Siemens, HMC etc. A check-valve is used instead of foot-valve as in Sardhana (Dist.Meerut) which is generally locally made.

Selection of pumpsets for rectification

The selection of pumpset was based on various parameters such as; (I) Capacity (hp) of the pumpset, (ii) make of the pumpset, (iii) water table, and (iv) Component/s to be rectified in the pumpsets. The appendix 3B, provides the details about the pumpsets covered for the study.

Six pumpsets were selected in Meerut study area and five pumpsets in Jaunpur. The capacities of the pumpsets selected were 3, 5, 7.5 and 10 horsepower. Six of the pumpsets were of 5 horse power capacity, three were 7.5 hp, and one each of 3 and 10 horsepower. The water table varied from 9.3 to 14.9 meters. The water table was very low in the Jaunpur study area Age of the pumpsets varied from newly installed to 25 years. The different makes of pumpsets covered for the study were, AI, Crompton, GEC, Siemens, AEI and also local i.e the pumpset that is manufactured in UP under the brand name other than the listed national brands. They do not posses ISI mark.

Detailed testing of the pumpsets before rectification

Before starting the rectification in any pumpsets it is necessary to know the level of its present efficiency. It has been established that if the energy index is less than 0.9 there is lesser need for rectification which also indicates that the performance of the pumping system is nearly at desirable level. More specifically, the Energy Index is the measure of energy efficiency in irrigation water pumping. It measures the electricity consumed to raise the 100,000 liters of water by one meter and is denoted by kWh/UIW means unit irrigation work. It was assumed that an EI of 0 9 KWh/UIW or less indicates an efficient pumping system. Only pumpsets with EI's greater than 0 9 were rectified. Thus, to find the out performance of the pumping systems certain parameter were measured i.e. rate of discharge, static head, consumption of electricity etc.

It was found that performance of only two pumpsets had a desirable level of energy index (less than 0.9). The average energy index was 1.068 kWh/UIW. The calculations on efficiencies show a range of 21 to 41% and the average efficiency was 27.98% Further details of individual pumpsets are provided in the (appendix 3F).

Rectification of pumping systems

The components to be rectified were identified mainly by observation of the physical condition. The energy index calculated based on the measurements conducted before rectification is another indication for the selection of pumping system for rectification. The details of the measurements are provided in the table 4.5 (Appendix 4C). An energy index higher than 0.9 indicate a need for rectification.

The details of rectification are given in the table below. The rectification was conducted

based on the need through observations and energy index calculations. The rectification conducted thus could be categorized mainly into two: (I) Major rectification, and (ii) Minor rectification.

Major rectification: Major rectification would involve, major overhauling of the pumping system involving. Replacement of suction and delivery pipes from GI to PVC, replacement of foot-valve, Changing of winding, alignment of shaft, replacement of bearing, bush, replacement of belt, general servicing etc. On an average about 2-3 days was spent in doing the rectification by the team during the present project. This again included time involved in measurements before and after rectification.

Minor rectification. Minor rectification involves minor repair and changes such as, bearings and bushes, changing of delivery pipe from GI to PVC It also would include general servicing such as greasing. The pumpset rectification thus would cost less than Rs 1200. The average time taken by the present team was about one day, which involved measurement of parameters such as, discharge, energy consumption before and after rectification, in addition to undertaking of rectification.

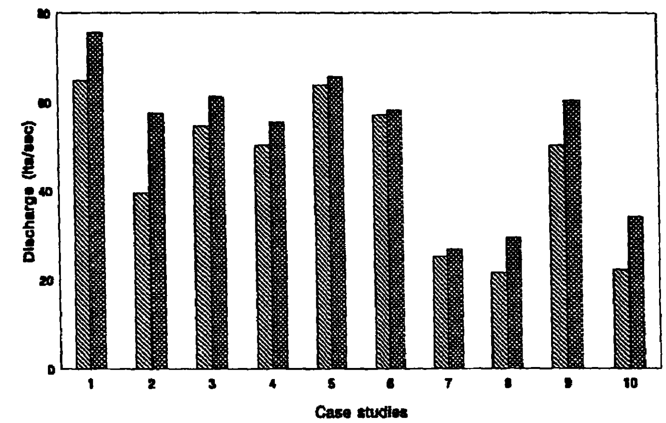
The cost of each of the component and the labour cost involved are provided for each of the rectification for different pumpsets. The costs varied depending on the quantity of the material used, for example, in some cases the cost of the pipe is higher because of the higher depth. The details of rectification conducted with cost details gives in the Appendix 3E The average cost thus comes to about Rs 2030 per pumpset on component and Rs 260 per pumpset on labour.

Comparative performance of pumping systems before and after rectification

There has been an overall improvement in all the rectified pumpsets However, the level of improvement varied from case to case depending on their earlier condition, capacity of pumpset and also on the type of rectification conducted. The average percentage enhancement (for 10 pumps) in discharge was by about 20.7% (7.52 cum/hr), reduction in energy consumption was by 21.24% (1.131 kWh), instead of 30-35% (based on other studies and demonstrations), to provide same quantity of water discharge. This is because of the rectification which was carried out only in those components which needed to be rectified instead of complete rectification. The average percentage efficiency enhancement was by 28.87 % (an overall increase by 7.35%, from 27 65% to 35.0% after rectification). The percentage improvement in energy index was up by 20.6% (reduction of EI by about 0.219 kWh/UIW) The details of the measurements conducted and calculated for each of the pumpset are given in the appendix 3F. Further details according to capacity and type of

rectification are provided for discharge, energy consumption and energy index in the later section of this chapter.

Discharge of the Pumpsets



Discharge (lts/sec) from various pumpsets under study

Figure 3.1

Discharge

The discharge measurements made after rectification clearly indicates, that there has been enhancement in all the ten rectified pumping sets. The average enhancement in discharge was 7.52 cum/hr (ranged from 1.1 to 18.0 cum per hour per pumpset). The figure 3.1 given below shows the increase in discharge in different cases. The average percentage enhancement was 20.70% (range 2.0% to 53.4%)

Discharge enhancement capacity-wise

Further, the discharge enhancement has been given in table 3.2.

Table 3 2 Discharge enhancement (cum per hour) capacity-wise and rectification type-wise

Details	Average discharge before rectification	Average discharge after rectification	Increase in discharge after rectification (cum/hr)	Average %
According to Capacity of the pumping system				
3	21.60	29.5	7.9	36.6
5	40 57	45 9	5 37	13 1
7.5	57.47	63 2	5.7	9 9
10	50 40	60 5	10 1	20.0
Average	45.00	52 52	7 52	20.70
According to rectification type				
Minor	57.13	59 87	2 74	4.8
Major	39.80	49.37	9 57	24 1

Implications of discharge enhancement The increase in discharge, could be used to irrigate same land which could perhaps result in increase in the productivity, bring more area under irrigation or even sell water or to increase the area under irrigation.

Increase of area under irrigation There are about 48,000 thousand PTW's in District Meerut and 24,000 in District Jaunpur. In our study, it was found that the average enhancement of water per hour due to rectification is about 7.52 cum per hour and also the total number of hours of pumpsets operation per year would be about 1600 hours. If it is assumed that the additional water is used for irrigating an additional land, keeping the number of hours of operation same, substantial (additional) land could be brought under irrigation.

Table 3.3 Implications of discharge enhancement

Details	Meerut district	Jaunpur district	Total
Total number of Private tubewells	47 802	24 127	71,929
Additional land under irrigation			
Enhancement of water output per hour (@ 7 52 cum/hr/pumpset)	360 960 cum/hr	181 435 cum/hr	542,395cum/hr
Enhancement of water output per day (8hrs operation per day)	2,887,680 cum/d	1,451,480 cum/d	4,339,160 cum/d
Additional land that could be brought under irrigation (at 50 cum ha water requirement per day)	57,754 ha	29,030 ha	86,784 ha
Water market calculations (for additional water)			
The total turnover from the water market (Rs/hr), assuming an output of 52 52 cum/hr and Rs 10 per hour, for 47802 pumpsets	Rs 68,728	Rs 34,545	Rs 103, 273
The total turnover of water market (Rs/day), assuming an output of 52 52 cum/hr and 8 hrs per day operation	549,824	276,367	Rs 826,191
Total turnover from water market (Rs/year), assuming 1600 hours of operation	109,964,800	55,272,000	165,236,800
Cost incurred in rectification	95,604,000	48,254,000	143,858,000
Reduction in hours of operation due to rectification for the same discharge			
Total number of hours of operation at present	1600 hrs		
Total water output per year per pumpset before rectification (45 cum/hr)	72,000 cum/yr		
New total number of hrs after rectification for 72000 cum	1371 hrs		
Total number of hours of operation before rectification (1600 hrs/pumpset/yr)	76,483,200 hours/year	38,603,200 hrs/yr	115,086,400

Approximate number of hours required per year for the same output (72000 cum/yr/pumpset) after rectification (for one pumpset - 1371 hours/pumpset)	65,536,542 hours/year	33,078,117hrs/yr	98,614,659 hrs/yr
Reduction in hours of operation for all the pumpsets	10,946,658 hours/year	5,525,083 hrs/yr	16,471,741 hrs/yr

Total Water output per year per pumpset after rectification (52 52 cum/hr)

Benefit to the farmer Assuming the additional water is sold at the rate of Rs. 10 per hour, a farmer can earn Rs 2230 per year (229 hours per year). Since the selling of water is a normal practice , for example in Gujarat, selling of water is predominant in the state, farmer sell the water at nominal price to poor who does not have their own pumpset. However, the investment would be about Rs 2000 for the rectification of the pumpset.

Energy consumption

The average energy consumption in all the ten pumpsets was found to be about 5 212 kWh/hr which would mean 0.86[15] kWh/hr/hp. This is however, is an overloaded condition. Generally 80% of the rated capacity is considered optimal loading. After the rectification, the average energy consumed was 4.865 kWh/hr would mean 0.8041 kWh/hp/hr However, if the consumption is calculated for the enhanced performance, keeping the discharge same, the energy consumption would be about 4.09 kWh/hr, which would mean 0.676 kWh/hp/hr

Table 3.4 Energy saving (average of pumpsets under study) calculations for the same discharge

	Energy consumption before rectification kWh per year	Energy consumed after rectification kWh per year	Energy savings kWh/yr	% change in annual energy consumption
Case (average of all the 10 pumpsets under study - 6.05 hp)	1379 (8340)	1080 (6530)	299 (1810)	21.6%

Note The average number of hours of operation per year is 1600 hours
The number in bracket are per pumpset of average capacity of 6.05 hp The numbers without bracket are per hp

Energy saving per pumpset per year. On an average about 1650 kWh/yr could be brought in per pumpset of an average capacity of 6.05 hp. (average of capacity of 10 pumpsets rectified) However, for a 5 hp pumpset the calculation indicate a saving of about 1315 kWh per year.

Further, if the analysis is made, based on the type of rectification, the consumption per pumpset reached an average of 1333 kWh and 1195 kWh per year per hp respectively for

minor rectification and major rectification respectively. However, the quantum of saving for minor rectification was 277 kWh/yr/hp and it was 69 kWh/yr/hp for major rectification. This imply (I) most of the pumpsets selected for major rectification adopt minor rectification measures, or (ii) sample selected for major rectification had better performance relatively. Thus this clearly indicated that there is urgent need for minor rectification since it has enormous potential for energy saving.

Table 3.5 Energy savings in Meerut and Jaunpur districts

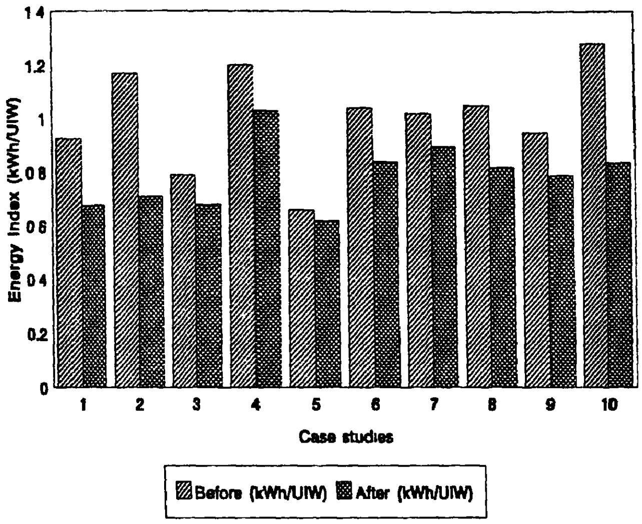
Details	Meerut district	Jaunpur district	Total
Total number of Private tubewells	47 802	24 127	71,929
Energy consumption per pump before	5 07 kWh/hr		
Energy consumption per pump after	4 865 kWh/hr		
Energy consumption per pump after rectification for the same discharge as before rectification	4 095 kWh/yr		
Average energy saving per year per year per month (for case 1)	1750 kWh/yr/pump		
Total energy saving for the same	83,653,500	42,222,250	125,875,750 kWh/yr
Total energy saving (in addition to enhancement of discharge from 45 to 52.52 cum/hr)	320 kWh/yr	320 kWh/yr	
Total energy saving per year in addition to enhanced discharge	15,296,640 kWh/yr	7,720,640 kWh/yr	23,017,280 kWh/yr

The energy saved per pumpset, thus, is 1750 kWh/yr (for an average 6.05 hp pumping system). Meerut district alone has about 47802 private tubewells, If the rectification is undertaken in all the pumping systems it would result in saving of about 84 mu (83,653,500 kWh) of energy per year.

Energy index (kWh/UIW)

Energy index calculations imply that, there has been improvement in all the rectified pumpsets. It was found out that, on an average, eight out of ten pumpsets, have an energy index (EI) of more than 0.9 (The pumpsets having EI more than 0.9 are categorist as inefficient pumpsets). The rectification in pumpsets conducted by us has brought down EI below 0.9 except in one case. It was one of the earlier pumpsets considered for rectification and only minor rectification was undertaken on this particular pumpset. Due to shortage of time, etc complete rectification could not be taken up. The average EI before rectification was 1 009 which was improved to 0 789. Further the improvement in rectification has been analyzed capacity-wise and rectification type-wise. The energy index before and after rectification are shown in figure 3.2.

Energy Index (EI) before and after the rectification



UIW - Energy required to lift one hecta-centimeter of water th a height of one meter

Figure 3.2

Energy index capacity-wise· The average EI capacity-wise for the different capacity pumpsets found in the study area has been analyzed and presented in the table below. The percentage improvement in energy index varied from 16.7 to 24.1%. It can be seen that percentage enhancement has been maximum for 5 hp pumpset.

Table 3 6 Energy index analysis capacity-wise (kWh/UIW)

Capacity of the pumping system (hp)	Average EI before rectification	Average EI after rectification	Average improvement	% enhancement
3	1 056	0 819	0 237	22 4
5	0 985	0 748	0.237	24 1
7.5	1 055	0.849	0.206	19 5
10	0 947	0 789	0 158	16 7

Table 3.7 Energy index analysis rectification type-wise (kWh/UIW)

Rectification type	Average EI before rectification	Average EI after rectification	Average enhancement in	% enhancement
Minor rectification (cost < Rs 1000)	0.966	0.83	0 137	14.18
Major rectification (> Rs 1000)	1 180	0 77	0.408	34 58

Post rectification measurements

Visits were made to the rectification (of pumpset) site only in Meerut study area due to lack of time. At the two sites, the rectification was disturbed and at one site farmer not found at his house, hence measurement were made only at three sites. In one pumpset the delivery pipe was broken down by animals and also the alignment between the pump and motor (as there was belt and pulley system in pumpset) was change by the farmer. While in second disturbed site, farmer shifted the motor daily to his home because of the fear of theft, thus, while connecting the motor with the electrical supply the motor had been burnt out.

Post rectification evaluation

Table 3 8: Discharge and energy index improvement/deterioration, immediately after and post rectification (2-4 months)

S N.	Capacity of the pumpsets	% change in the EI from before 2 immediately after rectification	% change in the EI from immediately after to 2-4 month after rectification
1	5 HP	13.9%	1 4%
2	7 5 HP	19 2%	1 19%
3	7 5 HP	25%	11%

The result shows that the percentage reduction in EI after post-rectification There has been significant reduction in the performance. The reduction in performance could be attributed to various things. However, since the maintenance by farmers, quality of power, repairs etc were not monitored, it would not be possible to give the exact reasons for the reduced performance. Since, the total number of hours operated after rectification was not large, the hours operated after rectification was not large, the reduction could be largely attributed to quality of power supply.

The details of the results of other parameters are shown in Appendix 3H.

Discharge

The graph (Figure 3.3) below provides clear picture of discharge for three of the pumpsets before rectification immediately after rectification and two to four months after rectification.

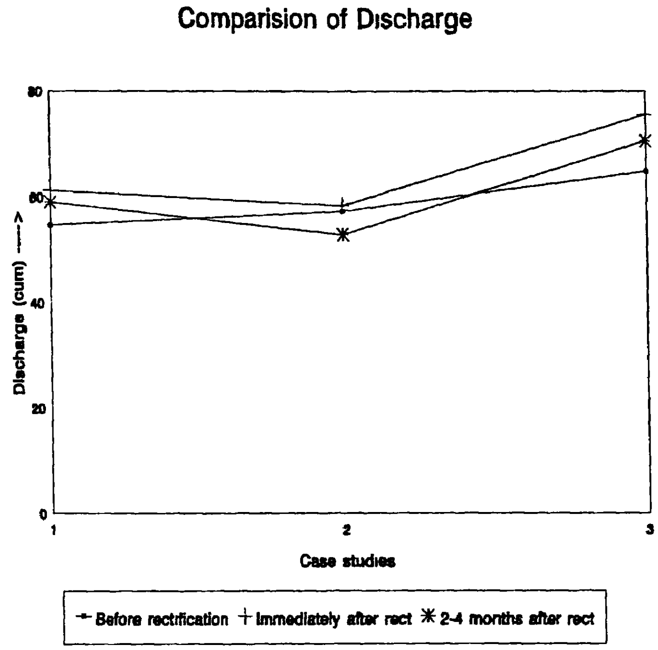


Figure 3 3

Figure 3.3 shows the discharge before rectification, immediately after rectification and two to four months after rectification.

The reduction in η observed was 3.53%, 9.44% and 6.67% respectively for case 1,2 and 3. Thus on an average the reduction was by 6.43%.

Efficiency

There has been a decrease in efficiency after 2–4 months after rectification when compared to immediately after rectification. The decrease in system efficiency was by 1%, 1% and 3% respectively for three cases (shown in the graph below) Thus the decrease in average system efficiency was by 1.67% which could be largely attributed to quality of power.

Comparision of Efficiencies (%)

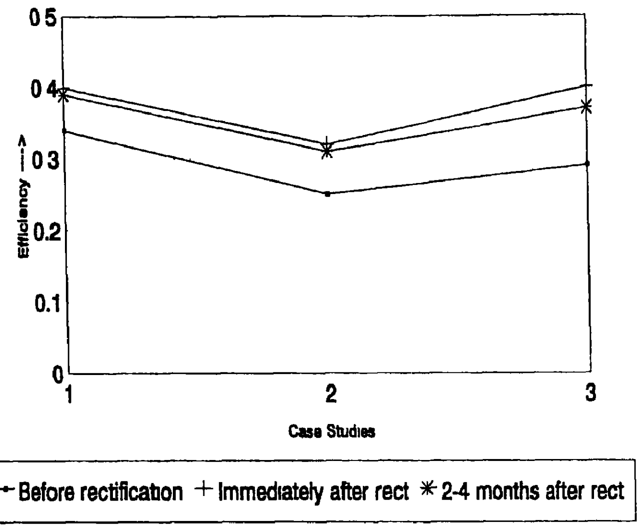


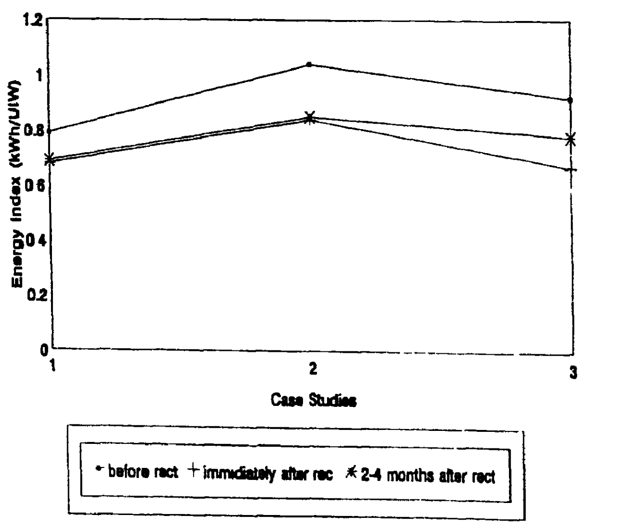
Figure 3 4

Figure 3.4 shows the system efficiency before, immediately after and 2-4 months after rectification.

Energy Index

Increase in energy index was observed in all the three cases. Increase in energy index is an indication of reduction in performance. The increase in energy index was by 0.01, 0.01 and 0.11 in the three cases respectively. Thus the average deterioration in energy index was 4.61%. The graph below shows energy index in difference in different situations.

Comparision of Energy Index (EI)



Lower EI indicate better performance

Figure 3.5

Figure 3.5 shows the energy index before, immediately after and 2-4 months after rectification.

Discussion and conclusions

Pre-rectification

- *Need for rectification*: 82% of the sample had energy index more than 0.9 kWh/UIW. It has been established that the pumpset having energy index more than 0.9 need rectification since their performance is poor which results in reduced discharge and excessive electricity consumption.

Rectification

- *List of components rectified*: (I) replacement of GI pipes with PVC pipes, (ii) replacement of foot-valve, (iii) bearings of pump and motor (iv) bush of pump, (v) electrical winding of motor, (vi) reducing sharp bends etc., (vii) replacement of check valves, (viii) replacement of belt and maintenance, such as greasing of the mechanical components.

- *Rectification details*: rectification was conducted on ten of the eleven pumpsets selected for measurements. The average cost per pumpset was about Rs. 2290. The component and material cost was about Rs 2030 per pumpset and Rs 260 was the labour cost per pumpset. This does not include the cost incurred in supervision etc.

- *Cost of Minor rectification*: In three of the pumpsets minor rectification such as, replacement of bearings, bush etc was undertaken. The total average cost of minor rectification was Rs 770 of which Rs 657 was component and material cost and the rest Rs 113 was on labour.

- *Cost of Major rectification*. In seven pumpsets, major rectification was undertaken. The total average cost was about 2942 per pumpset The total average cost of material was Rs 2619 and on labour Rs 323 per pumpset.

After rectification

- *Implications of discharge enhancement*: The results of discharge enhancement can be inferred in some of the following ways:

  (I) If used to bring an additional land under irrigation, 58 thousand hectares land in Meerut district and 29 thousand hectares land in Jaunpur could be brought under irrigation.

(ii) If used for water market, total turnover per year in Meerut district could be 110 million rupees and in Jaunpur district 48 million rupees per year.
(iii) If used to reduce the number of hours of operation to get same discharge, there would be a reduction of 229 hours per pumpset per year

- *Energy consumption*: Average energy consumption has reduced by 0.347 kWh per hour per pumpset (average pumpset capacity of 6.05 hp per pumpset) The average consumption has thus reduced from 5.212 kWh per hour before rectification to 4.865 kWh per hour in addition to an additional discharge of 7 52 cum per pumpset per hour If the electricity consumption is calculated for the same discharge, the savings would be about 0.98 kWh per hour per pumpset. The consumption of electricity for the same discharge after rectification would be about 4.09 kWh per pumpset per hour.

The average (of all the pumpsets) energy saving per hp of installed capacity is about 299 kWh. The average energy consumption before and after rectification was 1379 and 1080 kWh per hp year respectively.

Effect on energy consumption due to minor rectification The average energy savings due to minor rectification was about 277 kWh per hp per year The energy consumption before and after rectification was 1610 and 1333 kWh per hp per year respectively.

Effect on energy consumption due to major rectification. The average energy saving due to major rectification was about 310 kWh per hp per year. The energy consumption before and after rectification were 1264 and 954 kWh per hp per year respectively. Thus (the total energy saving in Meerut and Jaunpur districts for the same discharge before and after rectification would be 86 5 and 43.7 GWh/yr respectively.

OR

The total energy saving would be 26 6 and 13.4 GWh/yr respectively in Meerut and Jaunpur districts in addition to 5.75×10^8 cum/yr and 2.90×10^8 cum/yr

Efficiency: The increase in system efficiency of the pumpsets was 7 35%. The system efficiency increased form 27.65% before rectification to 35.0% after rectification. Thus the average percentage enhancement in efficiency was by 28.87%.

Energy Index (EI in kWh/UIW): 80% of the pumpsets selected for rectification had an energy

index more than 0.9. The average energy index before rectification was 1.068 (ranging from 0.66 to 1 28) The average energy index was brought down to less than 0.9 except in our case. The average energy index after rectification was by 0.789. Thus the improvement in energy index was by 0.219 an percentage improvement was 20.6%.

Post rectification evaluation results

A few (six) of the pumpsets when rectification was conducted were revisited after about 2-4 months. In two of the sites, the rectification measures were disturbed by the farmers for eg. the PVC pipe was removed. The enquiries revealed that PVC pipe was broken due to some reasons Measurements were taken in three sites.

Discharge: The discharge was found reduced in two of the pumpsets however, there was increase in one of the pumpset The average discharge per hp per hour before, immediately after 2-4 months of rectification was 9.30, 10.27 and 9 62 cum/hr respectively
Efficiency The decrease in average system efficiency after 2-4 months after rectification was by 1.67%, however, the average percentage reduction in percentage was 5 65

Energy Index: Increase in EI was observed in all the three cases. The average increase was by 0.103 kWh/UIW. Thus the average percentage deterioration was by 4.61%.

Inference Rectification is recurring expenditure however since, different components have different life cycles, the recurring expenditure still need to be established

CHAPTER 4

Load Shape Analysis

Background

Uttar Pradesh State Electricity Board (UPSEB) is responsible for supplying power to the different categories of consumers of the state of Uttar Pradesh In addition to its own generation UPSEB relies on exchanges of power with the National Thermal Power Corporation (NTPC), the Narora Atomic Power Station (NAPS), and other neighboring state electricity boards to meet its electricity demand The State Load Dispatch Center (SLDC) at Lucknow collects data on power generation and exchange of power with other utilities The load dispatch center also anticipates hourly system demand and dispatches power accordingly Primary, secondary and tertiary sub-stations at different voltage levels keep records of power flows through feeders Electricity consumption by customers in the residential, commercial, industrial, agricultural, and other (including public water works, street lighting, defense, and railways) sectors is determined based on billing data

The data available at Lucknow Load Despatch Center would enable detailed analysis to determine sector level load curves Such analyses along with information on the customer base would provide invaluable information on hourly and seasonal variations in demand imposed by customers in different sectors which, in turn, determine the cost of power supply and the hourly/daily and seasonal variations in these costs.

Introduction

Demand and load curve analysis is an important subtask of this DSM study for agriculture subsector In this subtask of the study, the supply of power to agricultural customers, was analyzed to determine the load served by UPSEB to agricultural sector. Data on power flow from the load despatch center was analyzed to obtain system level hourly load shapes. The system level hourly data was then disaggregated to obtain agriculture sector level load shapes. The methodology adopted for this study, the data collection efforts, data analysis, and results of these analyses are described in this chapter. It may be mentioned here that according to the primary survey done by TERI, it is assessed that power is supplied for 1600 hours in a year to agricultural loads. This assessment is based on the fact that for a little more than two months a year agriculture load is next to nil due to monsoon and off seasonal rains. The agriculture pattern is such that the load is very low just after harvesting of crops. As the regions grow two crops in a year there is a time gap between the two seasons. During times when the agriculture load is at its peak, the power is supplied for as much as twenty hours a day.

Objectives of load shape analysis

Load shape analysis is a perquisite for conducting any analysis of the cost of supplying power, impact analysis of strategies to change demand patterns or effect energy conservation, and impact of tariff revision. Coupled with costs and reliable load forecasts, system load shapes can be used to determine appropriate load shape to achieve objectives such as peak clipping, valley filling, strategic load growth, etc. which can be used to optimally plan new capacity requirements.

Sector and end-use level hourly load curves provide additional information on loads imposed by different categories of customers and their contribution to the system load shape. This information is useful for developing suitable strategies for different consumer groups which can help better design suitable tariff structures for equitable revenue realization, or decide on incentives/penalties schemes which may help meet load shape objectives. Sector level load shapes are also an indispensable tool in designing DSM programs which target end-uses in the appropriate sector to cost-effectively meet load shape objectives. In this study, system and agricultural sector load shape has been used to evaluate cost-effectiveness of DSM programs.

UPSEB system load shape

System description[1]

The UPSEB power system includes power generation from UPSEB owned power plants and exchanges of power with National Thermal Power Corporation (NTPC), Narora Atomic Power Station (NAPS) and other neighboring state electricity boards UPSEB directly supplies power to approximately 6 million customers in the state. The load dispatch center at Lucknow maintains records of all power flows from the various generating plants and purchase/sale of electricity. Power is evacuated and dispatched through 400 kV and lower voltage transmission lines. Primary and secondary distribution lines supply power to customer load centers. Sub-stations at different voltage levels record power flow to the load centers. Figure 4 8, 4.9 & 4 10 indicate the actual hourly loadings of the UPSEB system on typical days in summer, winter and monsoon seasons.

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[1] Source UPSEB's Statistics at Glance, 1994-95

Energy Consumption and Revenue by Sector

Description of sectors

The per cent distribution of electricity sales and revenue assessed in 1994-95 is shown in figure 4.1 and figure 4.1A. The agricultural sector is the largest consumer of power in the state accounting for 36.8% of total sales. The industrial sector with 24.3% of sales is the second largest consumer. The agricultural sector, therefore, strongly influences power demand in the state The agricultural sector receives power at both high and low voltage from transmission and distribution lines The load on these lines is largely for agricultural pumps, though some rural domestic and commercial loads would also be served by these feeders. The agricultural sector is largely unmetered and pays a fixed tariff based on the connected load. It is thus, perhaps, of greatest interest to UPSEB to understand loads in this sector and estimate their impacts on the system load The tariff for electricity sales of UPSEB to the various consumer sectors is so structured that the rates for agricultural sector supply are well below the Board's cost of production and Industrial sector tariff provides considerable subsidy to the agriculture sector Present average tariffs (1994/95) for the various sectors are given in table 4.1 Because of the low agricultural tariff and high magnitude of consumption of this sector, the SEB loss heavily in terms of revenue from agricultural power sales, as these losses are not fully made up by sales at higher rates to other sectors like Industrial etc.

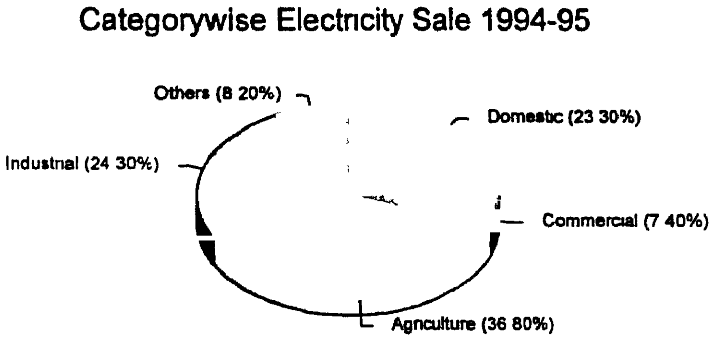


Figure 4.1

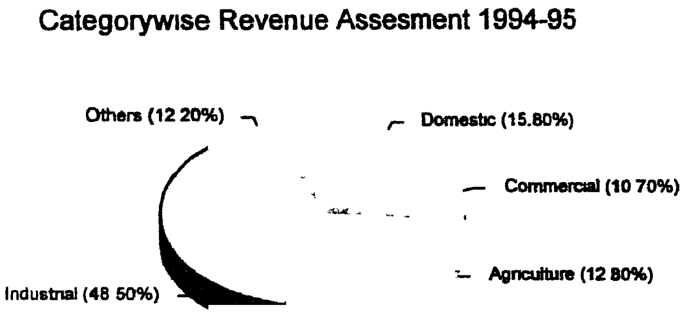


Figure. 4.1A

Table 4.1

Sl. No.	Consumer Class	Average tariff Rs/kWh
1	Domestic	0 82
2	Commercial	1 61
3	Agriculture	0.34
4	Industrial	2 24
5	Rly Traction	2 53

Figure below shows the yearwise and categorywise electricity sold in per cent

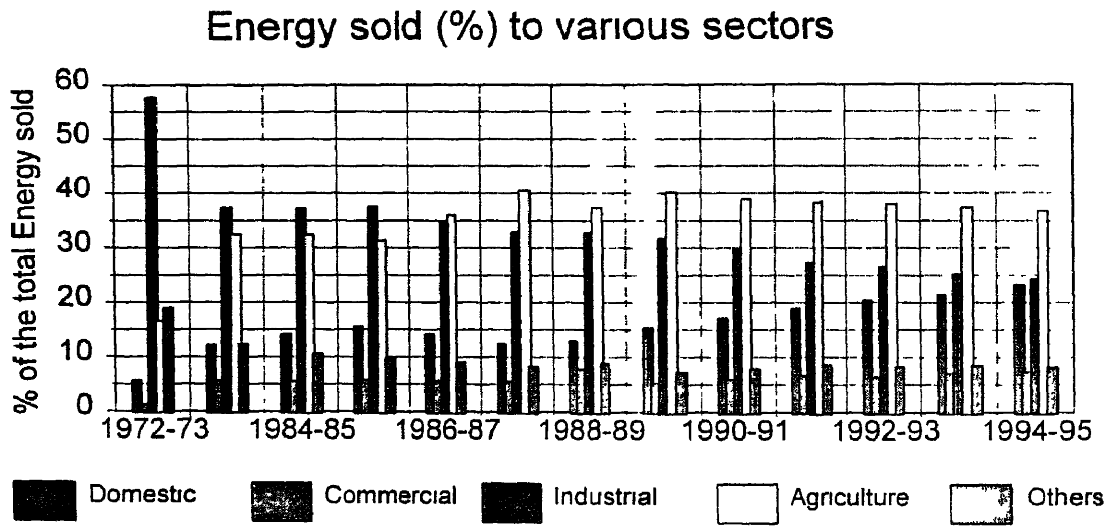


Figure 4 2

Methodology for developing agricultural sector load shape

To start with prior work on load shape analysis by UPSEB and other consultants were reviewed to develop baseline data sets. The review showed that though system level load shapes had been developed earlier, not much work had been done to develop sector level load shapes especially agriculture sector load shape and no attempt had been made to develop end-use load shapes The approach, therefore, was to identify new data required to develop such load shapes

For developing the agricultural sector load shape, two approaches has been attempted·

(a) Analysis of appropriate overall system daily load variation data of UPSEB system in recent past

(b) Analysis of data collected for few sample feeders supplying predominantly to agricultural loads

Development of Agricultural Load shape on the basis of overall system data analysis:

Table 4.2 shows the hourly system daily load data for five consecutive days for the month of January 1996.

Table: 4.2[2] Hourly loadings of the UPSEB system on four consecutive days in January, 1996.

	System Load (MW)				
Date/Hours	1-4	4-11	11-17	17-21	21-24
Jan. 1, 1996	4400	4900	4100	4400	4800
Jan. 2, 1996	4400	4700	4200	4400	3600
Jan. 3, 1996	3400	3600	3500	4500	4500
Jan. 4, 1996	4300	4600	3800	4100	4500
Jan. 5, 1996	4100	4300	3800	4400	3900

The hourly load data is divided into five time zones representing the average load during that time period. January 1, 1996 was a normal (non-rainy) day with the agricultural water pumps running routinely On the next day i.e January 2, 1996, rains started at around 21:00 hrs leading to a drop of 1200 MW compared to the previous day. The dropping of load ranging from 1100 to 700 MW continued between the hours of 1-4 a.m. of January 3 up to 17:00 hours in the same day, apparently at which time the rain stopped Normal pattern of system loading resumed between 17:00 of January 3, 1996 on onwards.

The reason for the sudden drop in loading of the UPSEB system as described above, was discussed at length with the engineers of UPSEB From the discussions it emerged that the predominant reason for this sudden drop of load was that during the rains the irrigation pumps were switched off. This clue has been made use of in the development of the load curve for the agricultural sector for January 1996 i.e. winter season as shown in figure 4.4. This load Shape is estimated on the basis of difference in loads from Jan 2,

Loadings on four consecutive days

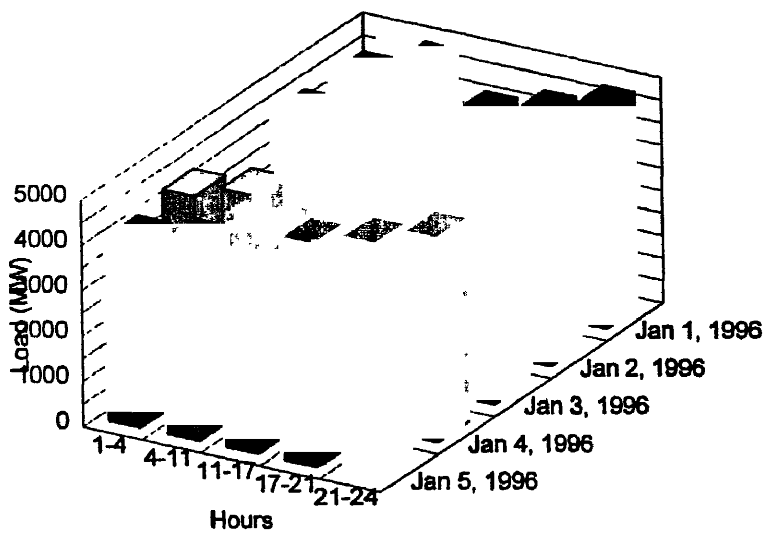


Figure: 4.3

[2]Source UPSEB's (Lucknow) Load Despatch Station

1996 and Jan 3, 1996. The figure shows the general trend of the agricultural load shape in UP in winter.

The load curves developed were discussed with engineers of UPSEB on April 15 and 16, 1996, at Lucknow. They were in general agreement with the methodology followed as well as the shape of the agricultural sector daily load curves developed.

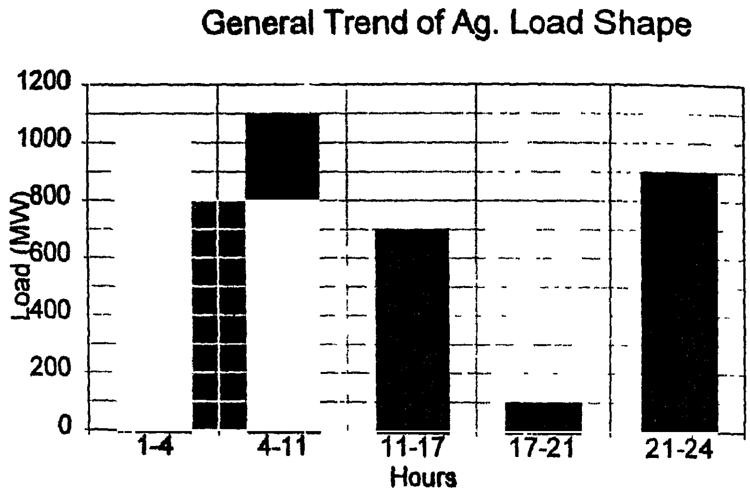


Figure: 4.4

Sample agricultural feeder data analysis for determining the agricultural sector load shape

After studying UPSEB data reporting systems and assessing data availability, TERI decided to use feeder data corresponding to summer, winter and monsoon seasons of a few typical predominantly agricultural feeders to develop load shapes for the agricultural sector. Feeder level data were collected from two sub-stations: 33 kV Sardhuna in Meerut (Western UP) and 33 kV Jalalpur (Eastern UP) in Jaunpur district which were identified for the pilot project in consultation with UPSEB. These sub-stations were considered as representative samples of the agricultural load pattern in other zones of the state. The hourly feeder load (kW) data were cross-checked with information on voltage, current, and power factor to reconcile irregular or missing data. Where load data were not available, the current loading on feeders was used in the load shape analysis. Electricity sales were used to provide the energy value for the load shapes.

Steps involved in establishing Load Shapes

(1) Log sheets containing hourly load data for three seasons were collected from Sardhana (Meerut) in Western UP and Jalalpur (Jaunpur) in eastern UP. Only rural feeders were taken for the study which are supplying power predominantly to the agricultural loads.

(2) Load Shapes were drawn for Sardhana (Meerut) for three seasons ie. summer, winter and monsoon from the hourly load data from the logsheets for the particular feeder. Similar load shapes were drawn for Jalalpur feeder (Jaunpur) from the logsheets collected from the Jalalpur substation. These load shapes formed the basis for developing typical daily load curves of the entire state for three seasons.

(3) U.P being a large state, some difference was observed in the load shapes of the eastern and western regions. An average load shape for a hypothetical representative 11 kV

feeder was determined for the entire state of Uttar Pradesh taking in to consideration the load shapes of both the regions and assigning hourly load values based on weighted average of the loadings of the two regions (vide figure 4.5 and appendix 4A). The weighted average was worked out assuming a ratio of 45:55 for agricultural loads in western and eastern U.P based on statistical data available in UPSEB publication "Statistics at Glance - 1994-95" The load shapes of eastern and western U.P along with their weighted averages for winter and monsoon are shown in figure 4.6 and 4.7 respectively.

(4) This average daily load curve developed for the representative feeder was suitably scaled up to correspond by and large to the agricultural load pattern developed on the basis of overall UPSEB system load shape discussed earlier and at the same time ensuring that the area under the curve represented the estimated total daily energy consumption in agricultural sector in the state

(5) The restricted load curve for a day was drawn by keeping the area under the curve equal to the amount of energy consumed by all the pumpsets in the state Whereas the unrestricted load shapes are scaled on the basis of total connected load of private tubewells in the state. The connected agriculture load in the state for the year 1994-95 is of the order of 3221000 kW. A diversity factor of 2 was assumed for energy calculations as suggested by Rural Electrification Corporation (REC).

Analysis of the load curves for examining DSM possibility corresponding to UPSEB

Restricted Load Shape

Summer (March/April/May)

Daily load curve of the UP power system for a typical day in summer (April 6, 1995) as furnished by UPSEB control room is shown in Fig 4.8. The corresponding load curve for the agriculture sub-sector showing the hourly load variations on the same day is also indicated in the same figure.

A scrutiny of the total system load curve reveals that UPSEB system is subjected to two daily peaks one between 7-9 hours in the morning, and the other between 19-22 hours in the evening. The morning peak (4750 MW) exceeds the evening peak (4400 MW) by about 350 MW.

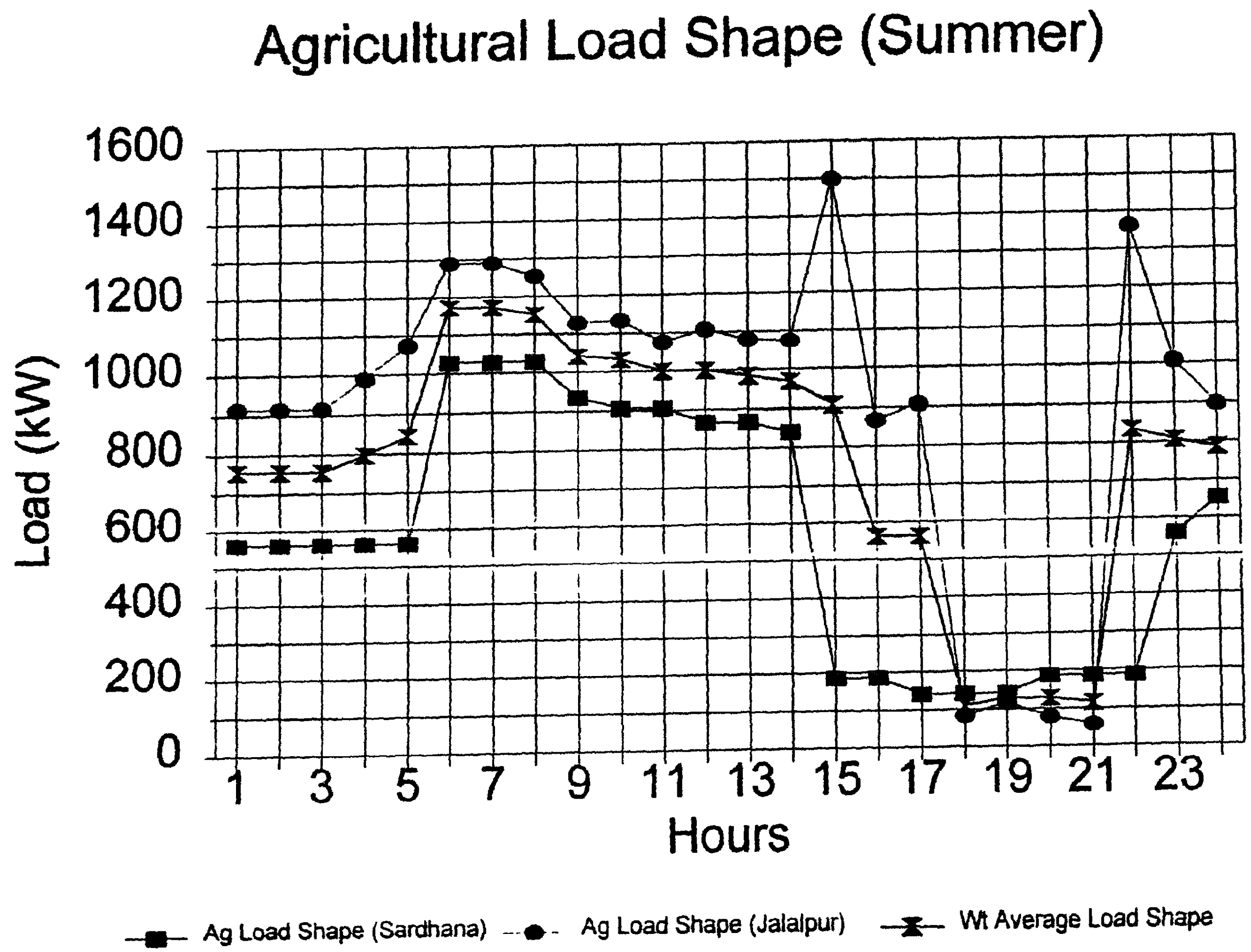

Agricultural Load Shape (Summer)
Load (kW)
1600
1400
1200
1000
800
600
400
200
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Ag Load Shape (Sardhana)
Ag Load Shape (Jalalpur)
Wt Average Load Shape

Figure 4.5

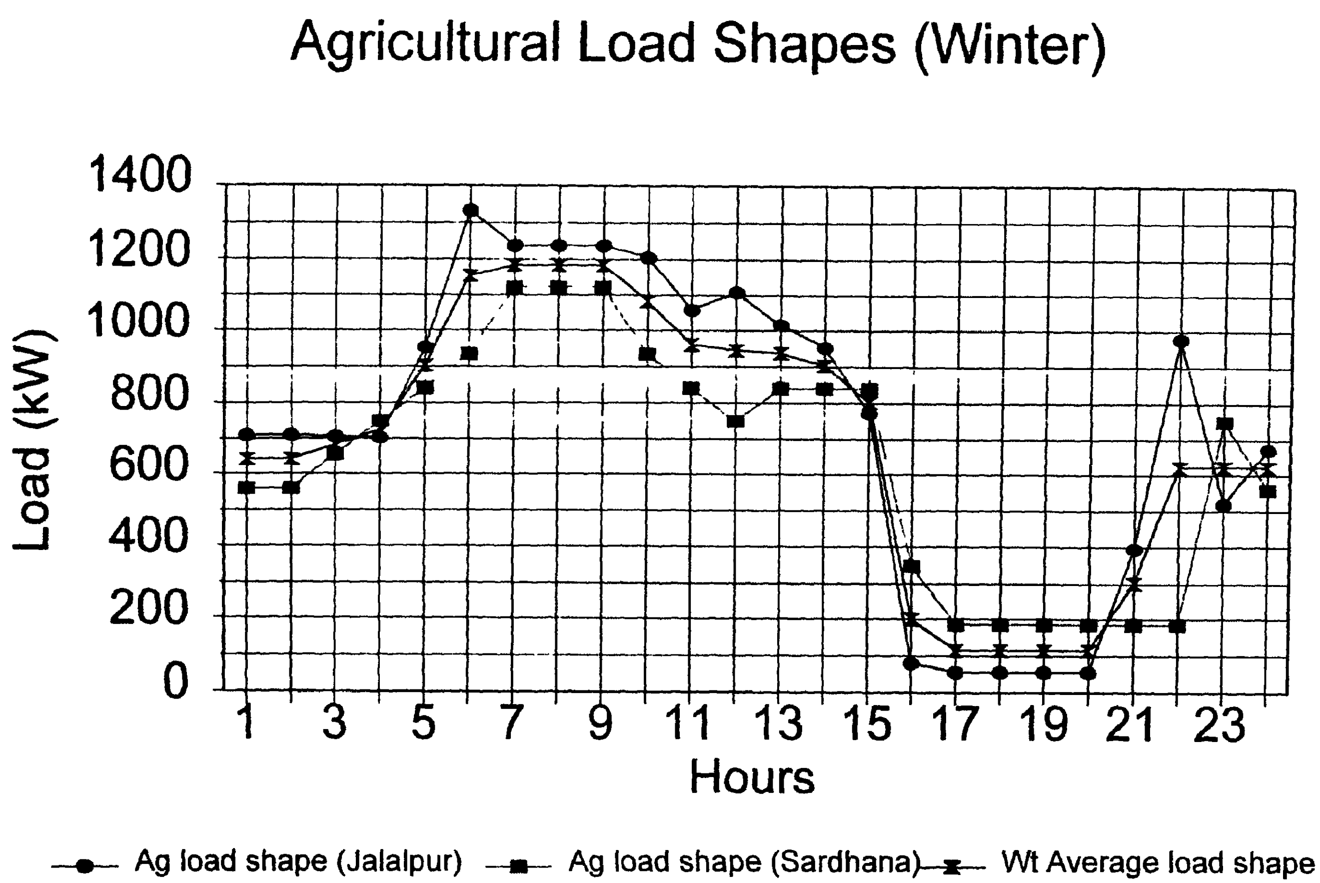

Agricultural Load Shapes (Winter)
Load (kW)
1400
1200
1000
800
600
400
200
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Ag load shape (Jalalpur)
Ag load shape (Sardhana)
Wt Average load shape

Figure 4.6

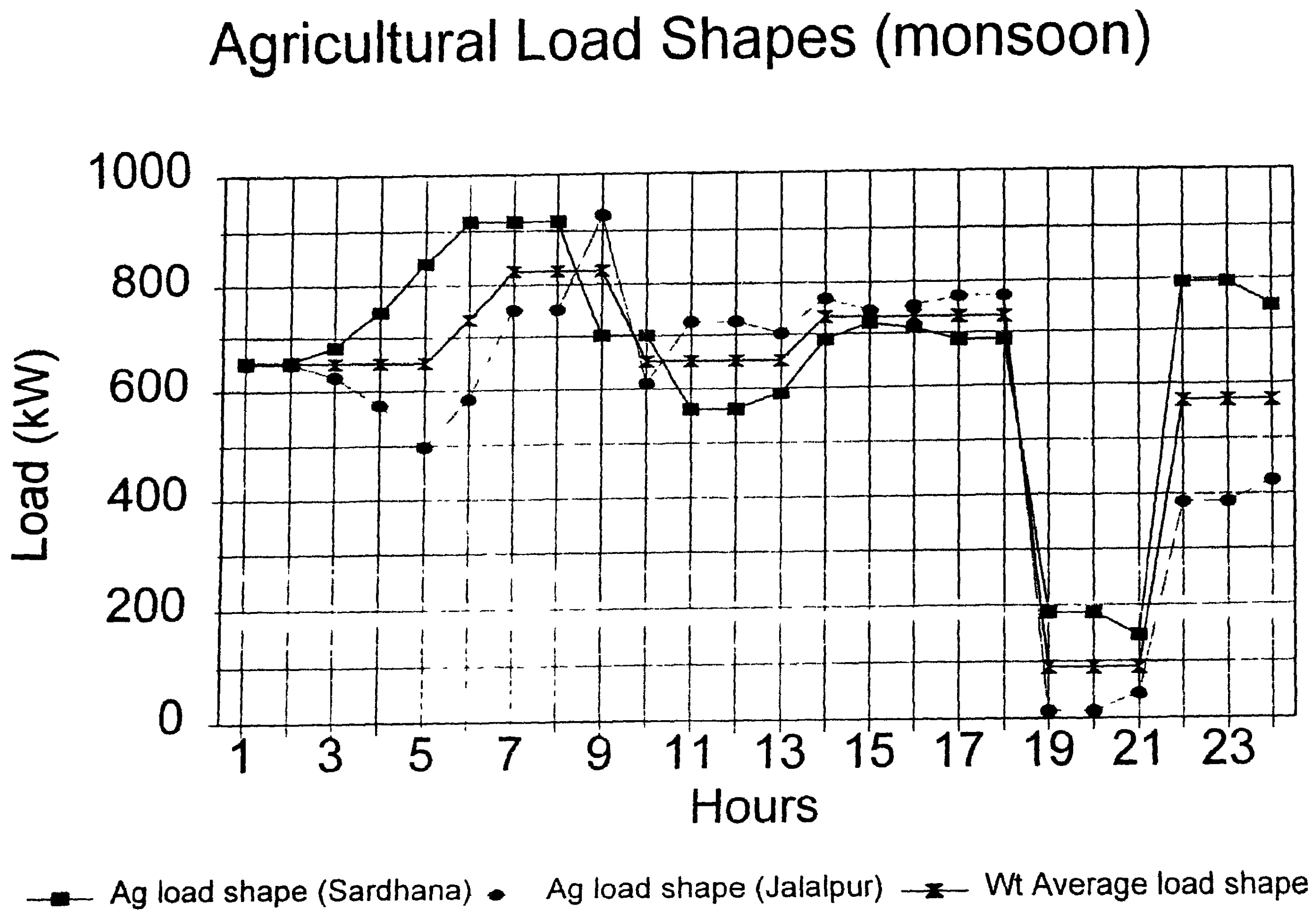

Agricultural Load Shapes (monsoon)
Load (kW)
1000
800
600
400
200
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Ag load shape (Sardhana)
Ag load shape (Jalalpur)
Wt Average load shape

Figure 4.7

In our DSM exercise, attempt has been to chop the morning peak to 4500 MW (between 7-9 hours) by corresponding reduction of the load contribution of agriculture during these hours, and make equivalent quantity of energy available to farmers during the other hours of the day (except between 17 and 22 hours). Thus the objective to be achieved was to effect a reduction in morning peak hour technical energy losses by flattening the UP system peak from present 4750 MW to 4500 MW, a reduction of 250 MW for 2 hours, without reducing the total number of hours of power supply to farmers for running their water pumps

How this objective can be achieved is indicated in Fig 4.8A. It is seen that by suitably filling up the valley in the load curve of the overall U.P system during 12-15 hours by suitable adjustment of the agricultural loadings during these hours, the system peak can be reduced by about 250 MW without reducing the total number of hours of power supply to agricultural feeders. From system operation considerations no difficulty is foreseen in implementing the above arrangement by suitably rescheduling the daily generation and daily routine maintenance programs

The above modified loading pattern of agricultural sector would result in a reduction of peak hour losses of 88.15 MW for 2 hours each day during the summer season. For detailed calculations refer to Appendix 4B. Assuming the summer season to consist of 90 working days, the total reduction in peak hour energy losses (2 hours duration) for summer would be 15.86 mu. Monetary savings to UPSEB due to savings in fuel cost would account to Rs 8.409 millions (US$ 240257.14).

Winter (November/December/January)

Daily load curves of the system as well as the agriculture load for UP are shown in Fig 4.9. The system peak for winter occurs twice: once in the morning between 6-8 hrs and once in the evening between 21-24 hrs. The morning peak is 4950 MW and the evening peak around 4900 MW. So there is not much difference between the morning and evening peaks. An attempt has been made (vide figure 4.9A) to chop the morning peak to 4650 MW during 6-8 hours. The reduction in the morning peak by 300 MW during 6-8 am (2 hours) and the corresponding energy is supplied to the agriculture load during the afternoons from 10 to 13 pm. There is no saving in the overall peaking capacity requirement as the evening peak still remains high at 4900 MW. The above modified loading pattern of agricultural sector would result in a reduction of peak hour losses of 153 43 MW for 2 hours every day during the winter season. Assuming the winter season to consist of 90 days, the total reduction in peak hour energy losses (2 hrs duration) would be 27.62 mu. Monetary savings to UPSEB due to savings in fuel cost would amount to Rs 14.637 millions (US$ 418228.57) (sample calculations for summer condition are given in Appendix 4B). Scope for DSM through agriculture is not much for evening hours as very nominal agricultural load is supplied during the evenings and its contribution to the system peak is minimal.

Monsoon

The restricted load shape of UPSEB system for a typical day in the monsoon is shown in Fig 4.10. The same curve shows the load shape of the agricultural sector.

It is seen that as compared to summer and winter seasons, in monsoon, there is not much variation in the system loads (4000-3500 MW) during the day, and also for agriculture load it varies in the range of 1100 MW-1300 MW except during the evening peak hours when agriculture load is negligible. Thus scope for DSM by adjusting agriculture load hours during monsoon season is not much

DSM study with UPSEB's unrestricted load demand projections

The discussions covered in the above paragraphs regarding the load shapes are based on the pattern of load demands actually being met by the UPSEB system However according to UPSEB these load demands do not reflect the real load demands of the Board's consumers as there is a large quantum of unfulfilled demand which UPSEB is not able to meet due to shortfall in available generating capacity This compels the utility to roster the power supply to various subsectors - especially to the industrial sector to match the loads with the available generation capacity For this purpose the cuts imposed on various sectors are notified from time to time, the magnitude of cuts imposed varying from day to day and from season to season

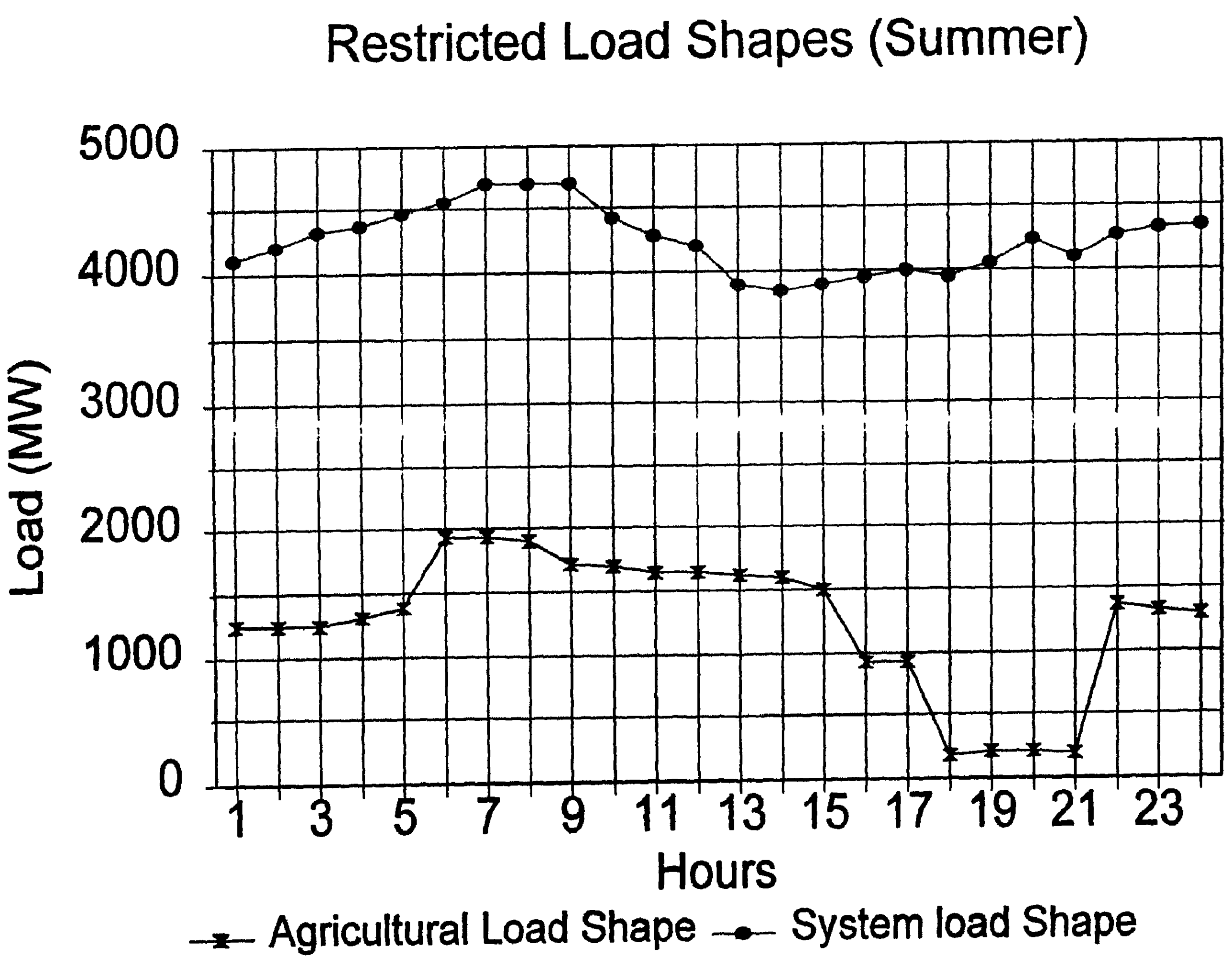

Restricted Load Shapes (Summer)
Load (MW)
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Agricultural Load Shape
System load Shape

Figure 4.8

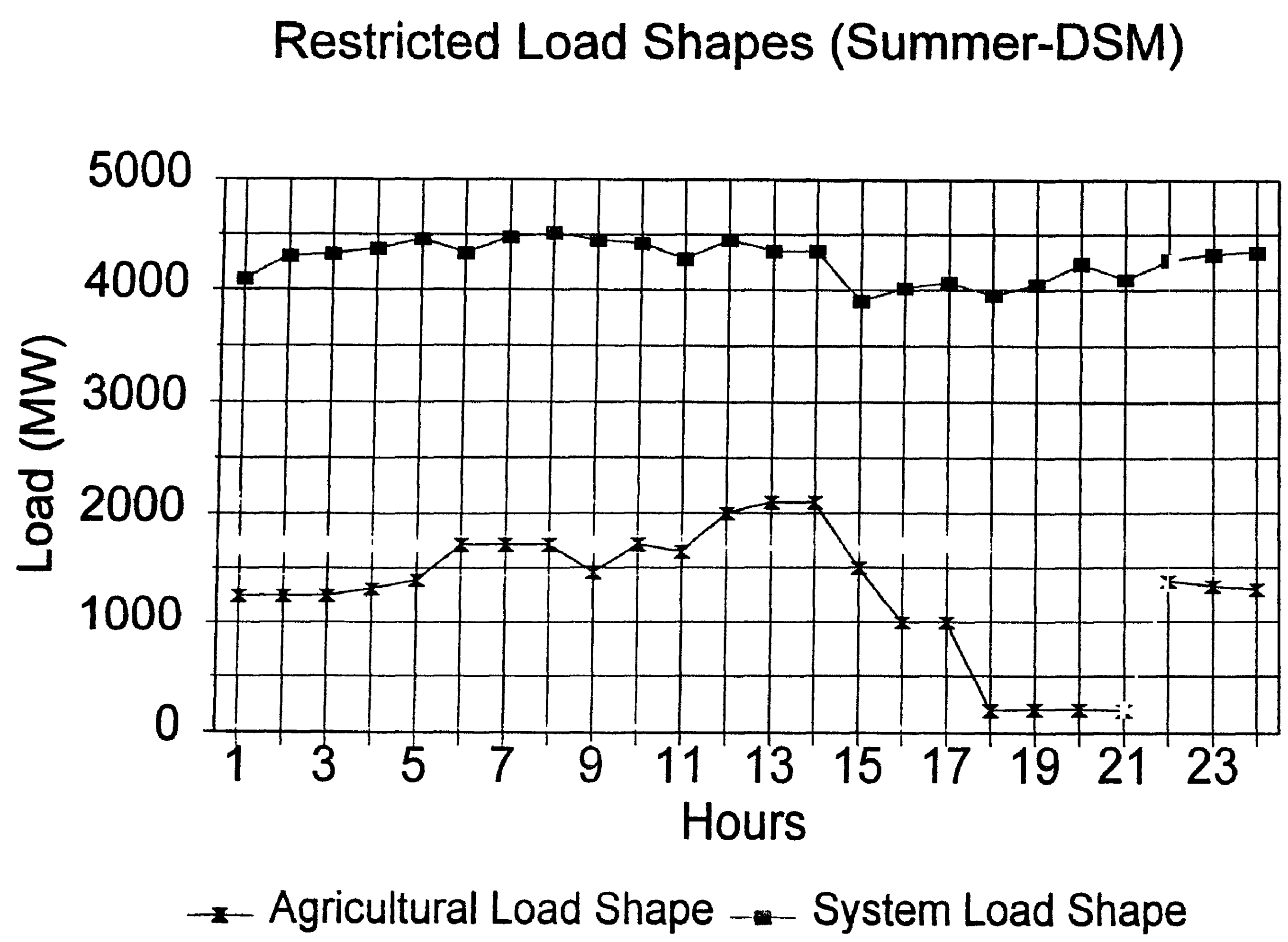

Restricted Load Shapes (Summer-DSM)
Load (MW)
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Agricultural Load Shape
System Load Shape

Figure 4.8A

For agricultural sector also heavy rostering is done round the clock, the total number of hours of supply being generally of the order of 10-16 hours per day. During evening peak hours (6 p.m - 10 p.m) supply to agriculture is severely restricted. UPSEB Lucknow State Despatch Station in their daily system load variation report, in addition to the pattern of hourly systems actually met also projects unrestricted load demand, which according to their assessment represents the true system demand of the state However, it must be noted that it was clarified by UPSEB during our discussions with the load despatch staff that these assessments are not based on any real time data or any scientific basis but are entirely of a subjective nature being the guess estimates of the shift operating staff

In the meeting with the World Bank officials held in New Delhi on March 14, 1996 to review the present project, it was desired by them that the DSM study should also be done on the basis of unrestricted demand of UPSEB system as projected by them in the daily reports of the Board's Lucknow Despatch Station Accordingly in addition to the study done by TERI on the DSM possibilities in the real time current power supply scenario of UP, DSM possibilities on the unrestricted system demand projected by UPSEB in their daily load despatch reports has also been carried out

Unrestricted load shapes of UPSEB system

UPSEB system unrestricted daily load curves for the studies are based entirely on the unrestricted hourly load curves indicated in the daily load curves of the UPSEB system furnished by the Boards' load despatch station at Lucknow and no attempt was made in the present studies to verify the accuracy of these load demand projections.

The system load curves of typical working days in the three seasons viz, summer, monsoon and winter in 1994 is shown in Figures 4 11, 4.12 and 4.13.

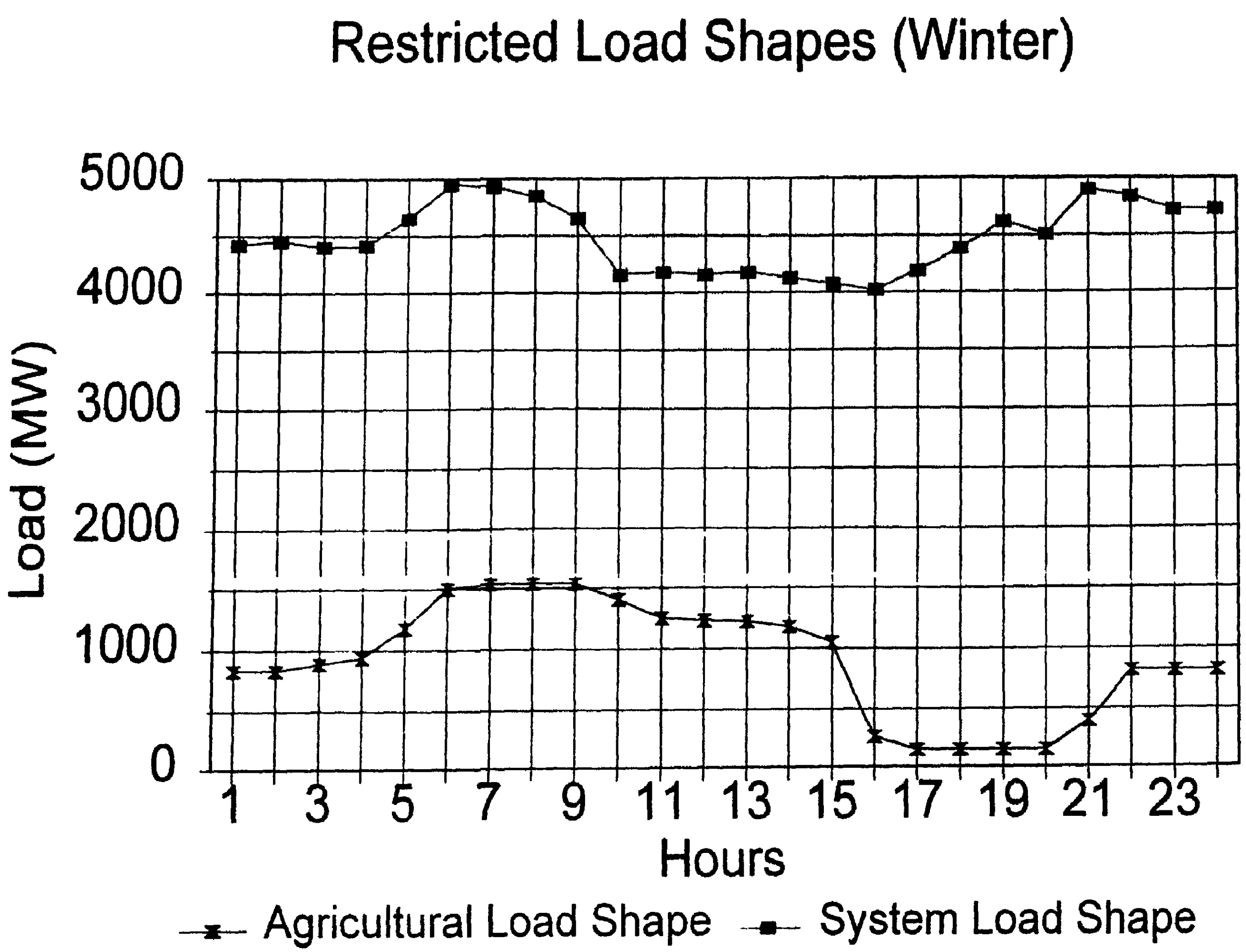

Restricted Load Shapes (Winter)
Load (MW)
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Agricultural Load Shape
System Load Shape

Figure 4.9

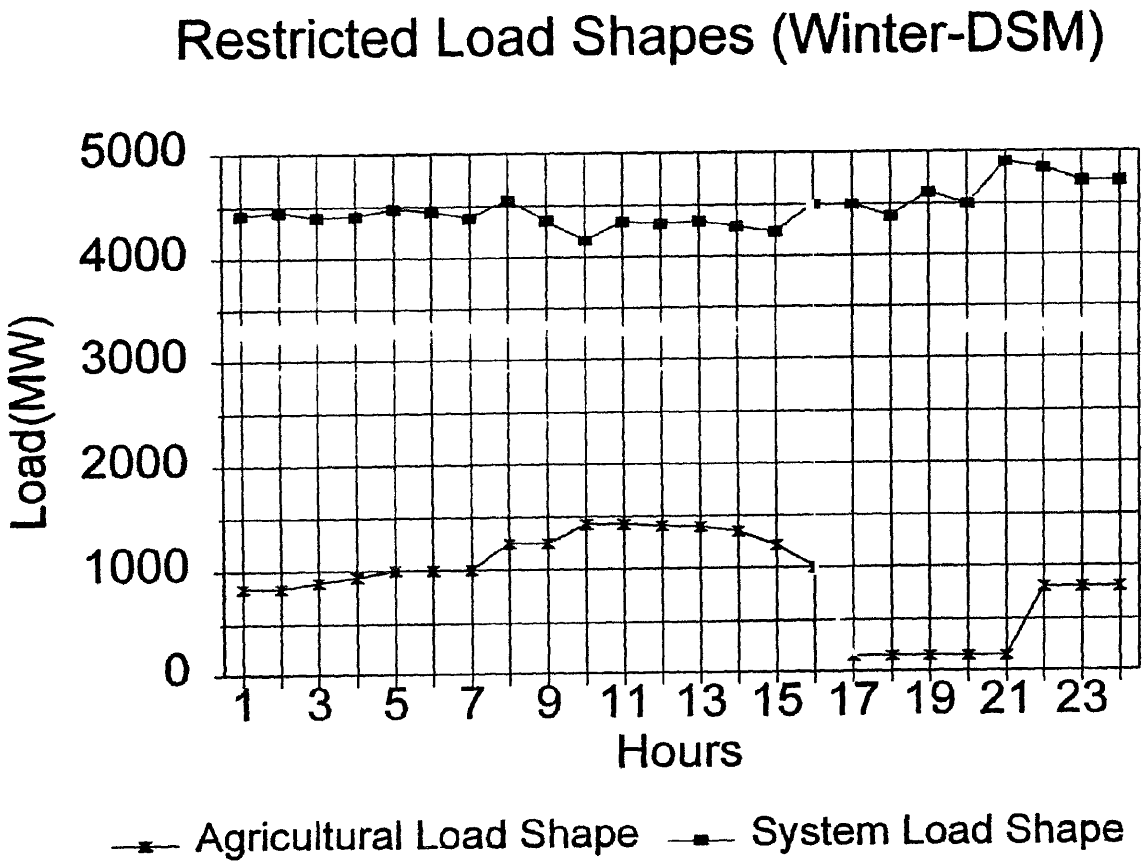

Restricted Load Shapes (Winter-DSM)
Load(MW)
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Agricultural Load Shape
System Load Shape

Figure 4.9A

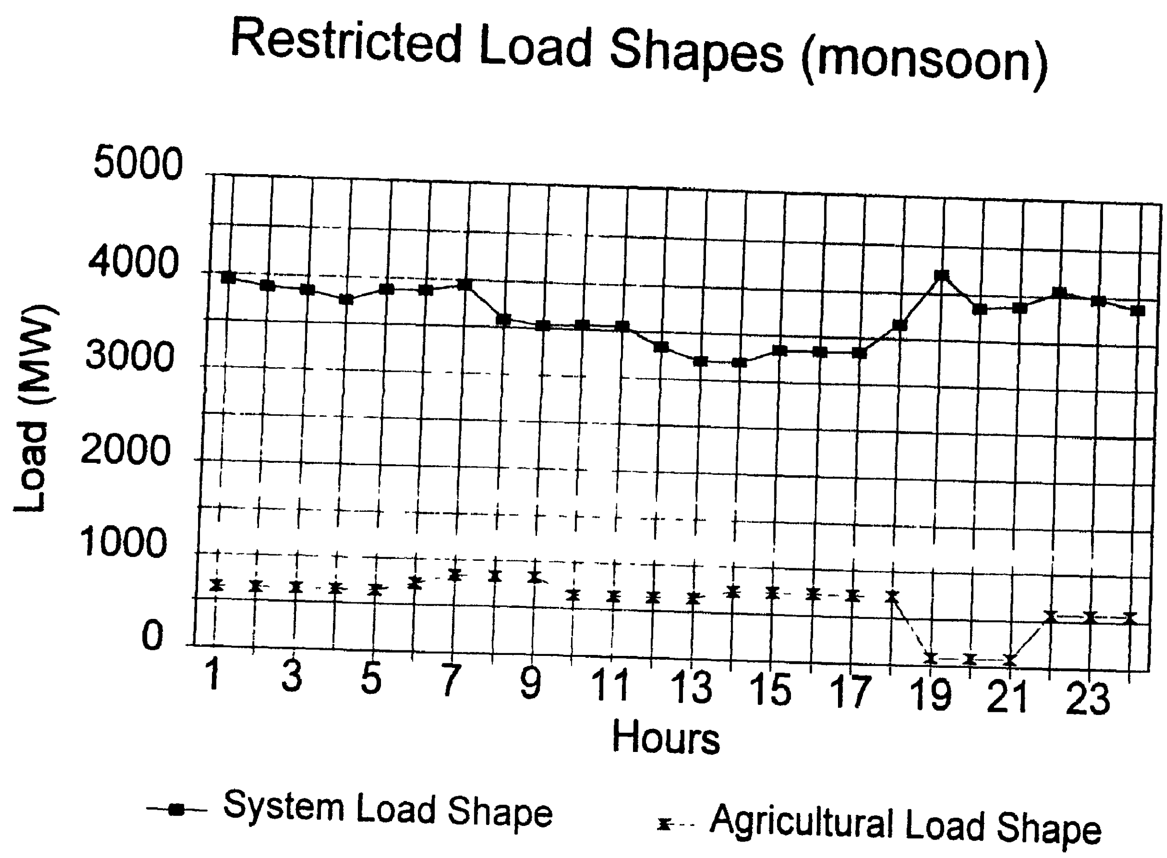

Restricted Load Shapes (monsoon)
5000
4000
3000
2000
1000
0
Load (MW)
1
3
5
7
9
11
13
15
17
19
21
23
Hours
System Load Shape
Agricultural Load Shape

Figure 4.10

Development of Agricultural sector load shape (unrestricted)

It is assumed that power is supplied for 1600 hours in a year to agriculture loads. It was understood that for about two months in a year, the agriculture load in UP is next to nil due to monsoon and off seasonal rains. The agriculture pattern is such that the load is very low just after harvesting of crops. As the regions grow two crops in a year there is a time gap between the two seasons During times when the agriculture load is at its peak according to UPSEB, the power is supplied for as much as twenty hours a day So for an average day for the whole year around it can be assumed that power is supplied for about 6 hours per day.

Considering the fact that around 700 thousand pumpsets (connected load) are supplied power, the net energy consumption is of the order of 4238424 MWh/year In a similar way as in the case of restricted load the load curve for a single feeder is developed taking the average of the load data from a feeder each in western and eastern U P. The feeders chosen are the same as those chosen in the restricted case The energy consumption of a single feeder is calculated by finding the area under the curve (average for the state). The graph is scaled up for a factor which is the ratio of the net energy consumption (from connected load) for the state and the energy consumption of the average feeder. Three such curves are again developed, for each for summer, winter and monsoon, and are shown in Figures 4.11, 4.12 & 4 13

Analysis of the load curves for examining DSM possibility corresponding to UPSEB unrestricted load shape

Summer

The load curve of the system for summer shows a morning peak of 5400 MW between 5-7 am which is 150 MW less than the evening peak of 5550 MW occurring between 19-24 hrs. The shape for unrestricted agricultural load shows a morning peak after 5 am which throws light upon the fact that the farmers if given unrestricted supply would prefer to utilize it only after day break and preferably during day time.

The system load curve remains almost flat at about 4200-4400 MW between 10 am and 5 pm. Naturally this would suggest that (subject to system operational constraints) this offers an opportunity to shift some of the sub-sectoral loads like industrial, commercial etc. categories to this time period so as to reduce the system loading during the two peaking periods in the morning and evenings. Since the scope of the present study is limited to the agricultural sector alone, the study concerns itself with the feasibility of achieving the purpose through suitable adjustment of agricultural loads during these periods.

As far as evening peak hours is concerned, for example it is seen from the daily load curve of April 6, 1995 furnished by Lucknow load dispatch station that the gap between the unrestricted demand of 5500 MW and the demand actually met (4300 MW) was 1200 MW.

As regards the morning peak hours, the UPSEB demand curve shows that during these hours, against the restricted demand of 4650 MW, UPSEB's unrestricted demand is 5450 MW thus the shortage is of about 850 MW. Discussions with UPSEB engineers revealed that the unfulfilled demand of 850 MW during early morning hours consists mainly of agricultural load demands, while the predominant components of evening peak of the system are industrial and commercial loads. Therefore for agricultural load demand adjustment in the present study, it has been assumed that the supply to this sector during evening peak hours would continue to be severely restricted as is being done by UPSEB at present. UPSEB engineers agreed with this view.

DSM was achieved in this case by clipping off the peak at 6 am from 5450 MW to 5000 MW (vide Fig 4.11A). The system as well as agricultural demand decreased by an amount of 450 MW. This amount of energy saved in the morning peak is supplied to the agricultural sector between 12-16 hours when the system experiences a slump in the load. Care was taken to see that the reduced energy supplied during 5-7 hours is compensated between 12-16 hours as can be seen from the Fig 4 11 and 4.11A.

The above modified loading pattern of agricultural sector would result in a reduction of morning peak hour losses of 174.4 MW during the summer season. Since system losses are directly proportional to the square of MW line loadings, peak chopping ie. reduction in system MW loading results in substantial savings in system I^2R losses. Assuming the summer season to consist of 90 days, the total reduction in peak hour energy losses (2 hrs duration) would be 15 70 mu. Monetary savings to UPSEB due to savings in fuel cost would amount to Rs 8.32 millions (refer Appendix 4B).

Apart from the above saving the modified pattern of loading would result in reduction of the system peak demand from 5450 MW to 5000 MW during morning peak hours effecting a capacity saving of 450 MW. However, this capacity saving is entirely notional, since the system demand would again rise to 5500 MW (i e. nearly the same value as the morning peak) in the evenings For reduction of the evening peak demand, load management measures are required to be studied for other sectoral loads like industrial, commercial, domestic etc. which is beyond the scope of the present study. As far as agricultural sectoral load is concerned this has hardly any role to play for load management purposes during evening peak hours as supply to irrigation tubewells is already severely restricted at present and will continue to be restricted in the future scenario also.

Winter

The unrestricted load shape for winter shows a peak of 5550 MW between 6-9 am in the morning which is higher by about 250 MW than the evening peak of around 5300 MW between 19-22 hours. There is a dip in the system load between 12 and 17 hours. During the same time the agricultural load also has a dip though not to the extent to which the system load decreases, which is an indication that the decrease in load is due to load sectors other than agriculture. Part of the system loads mainly industrial could be shifted to this lean period

to reduce the evening peak. Unrestricted load shapes for winter are shown in figures 4.12 and 4.12 A.

As far the morning peak, as shown in Figure 4.12A, it is possible to flatten the system peak by about 300-500 MW between 6 and 9 hours by suitable adjustment in the hourly schedules of the working of the irrigation pumps as indicated in the figure and at the same time ensuring that total energy supplied to agricultural sector over the day remains the same.

Due to chopping off of the peak loadings during the morning hours as discussed above there is a reduction of peak hour losses of 243.03 MW (1 hrs duration) during the typical day chosen for the winter season. Assuming the winter season to consist of 90 days, the total reduction in peak hour energy losses (1 hrs duration) would be 21 87 mu. Monetary savings to UPSEB due to savings in fuel cost would amount to Rs 11.59 millions (US$ 331142.85) (refer Appendix 4B)

Monsoon

As in the case of restricted loads for monsoon, for unrestricted load case also there is not much scope for DSM by adjustment of agricultural working hour loads The unrestricted load shapes are given in figure 4 13.

The comparison of the system load shapes for three seasons with and without DSM implementation are shown in figures 4 14, 4.15, 4 16 and 4 17

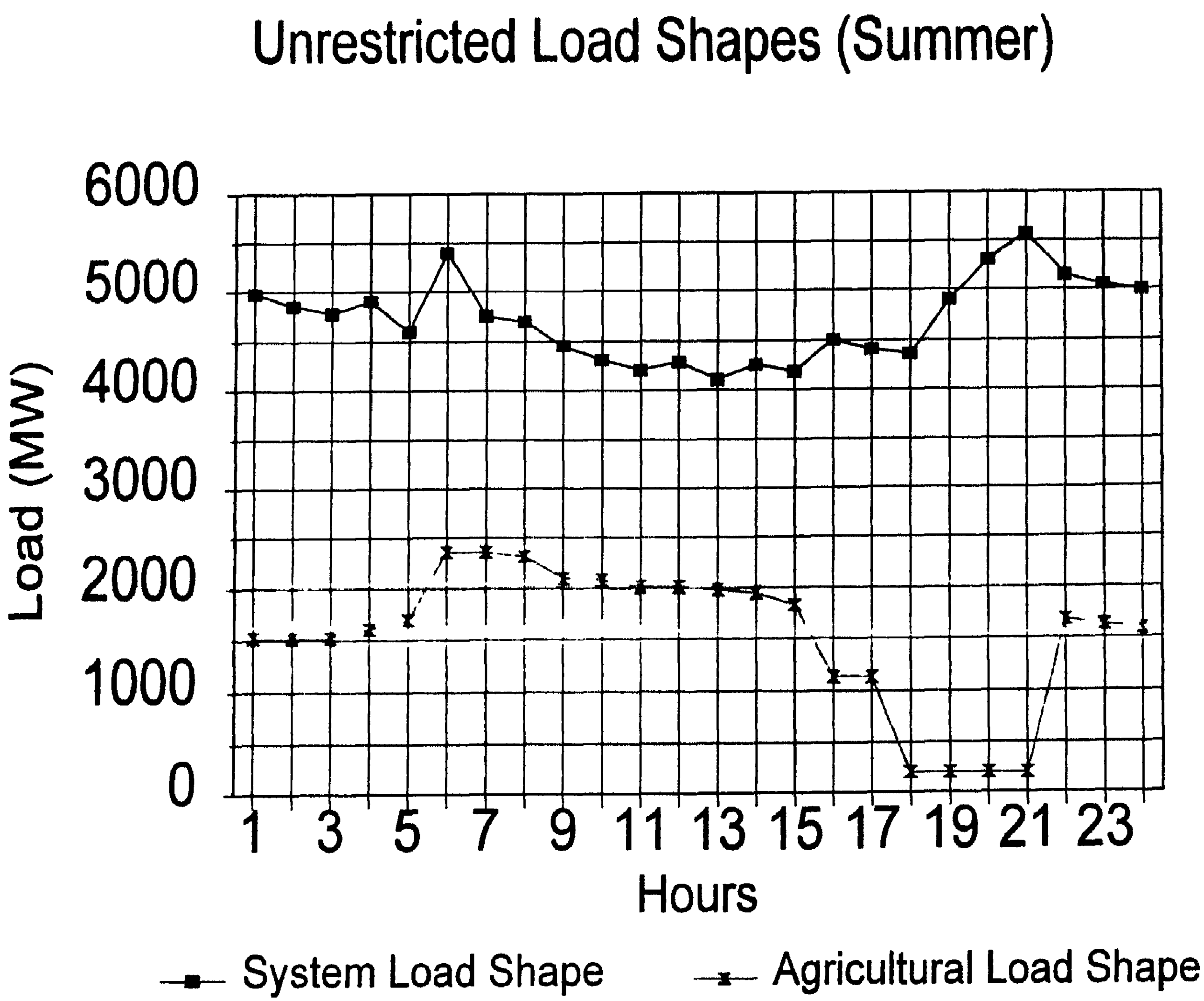

Unrestricted Load Shapes (Summer)
Load (MW)
6000
5000
4000
3000
2000
1000
0
1 3 5 7 9 11 13 15 17 19 21 23
Hours
System Load Shape
Agricultural Load Shape

Figure 4.11

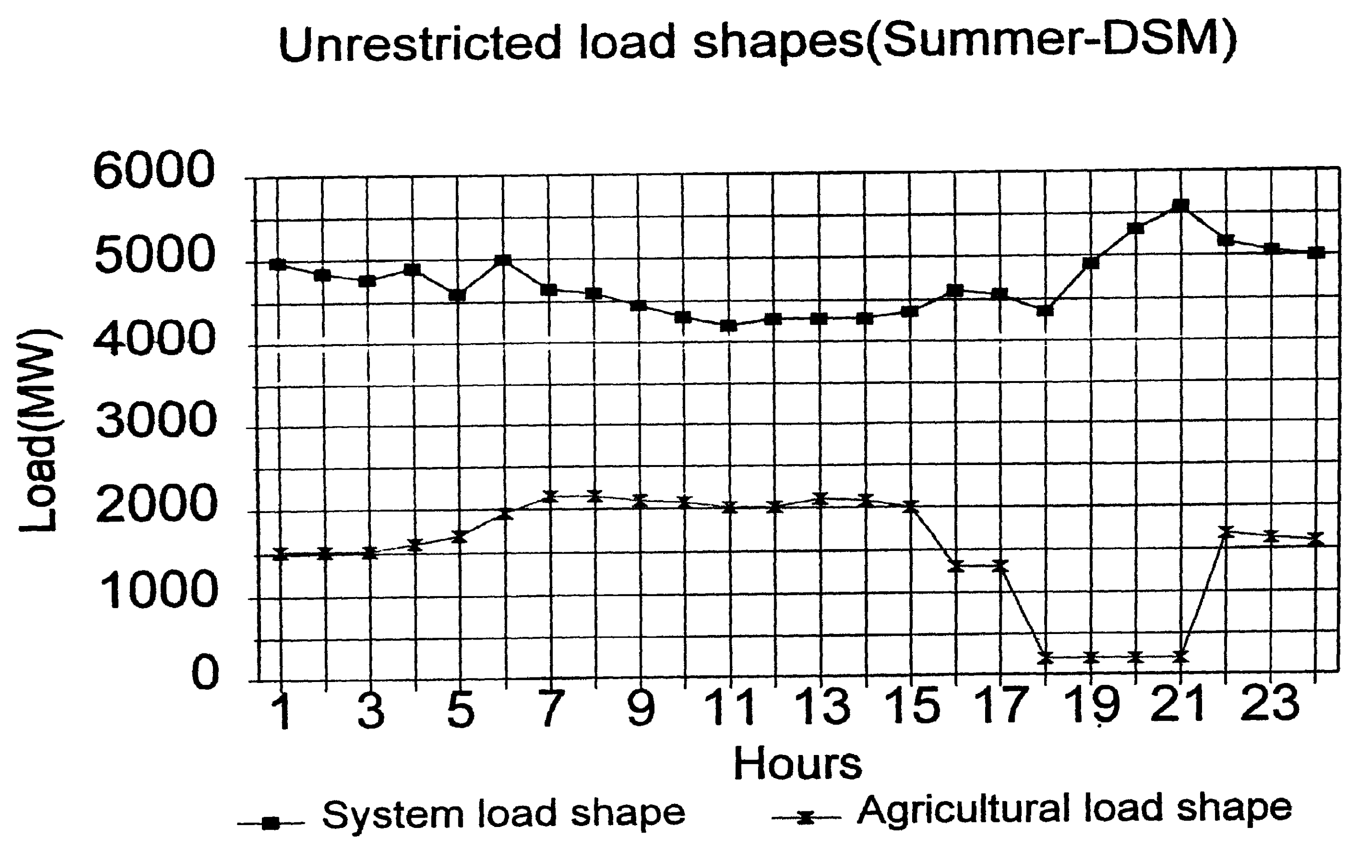

Unrestricted load shapes(Summer-DSM)
Load(MW)
6000
5000
4000
3000
2000
1000
0
1 3 5 7 9 11 13 15 17 19 21 23
Hours
System load shape
Agricultural load shape

Figure 4.11A

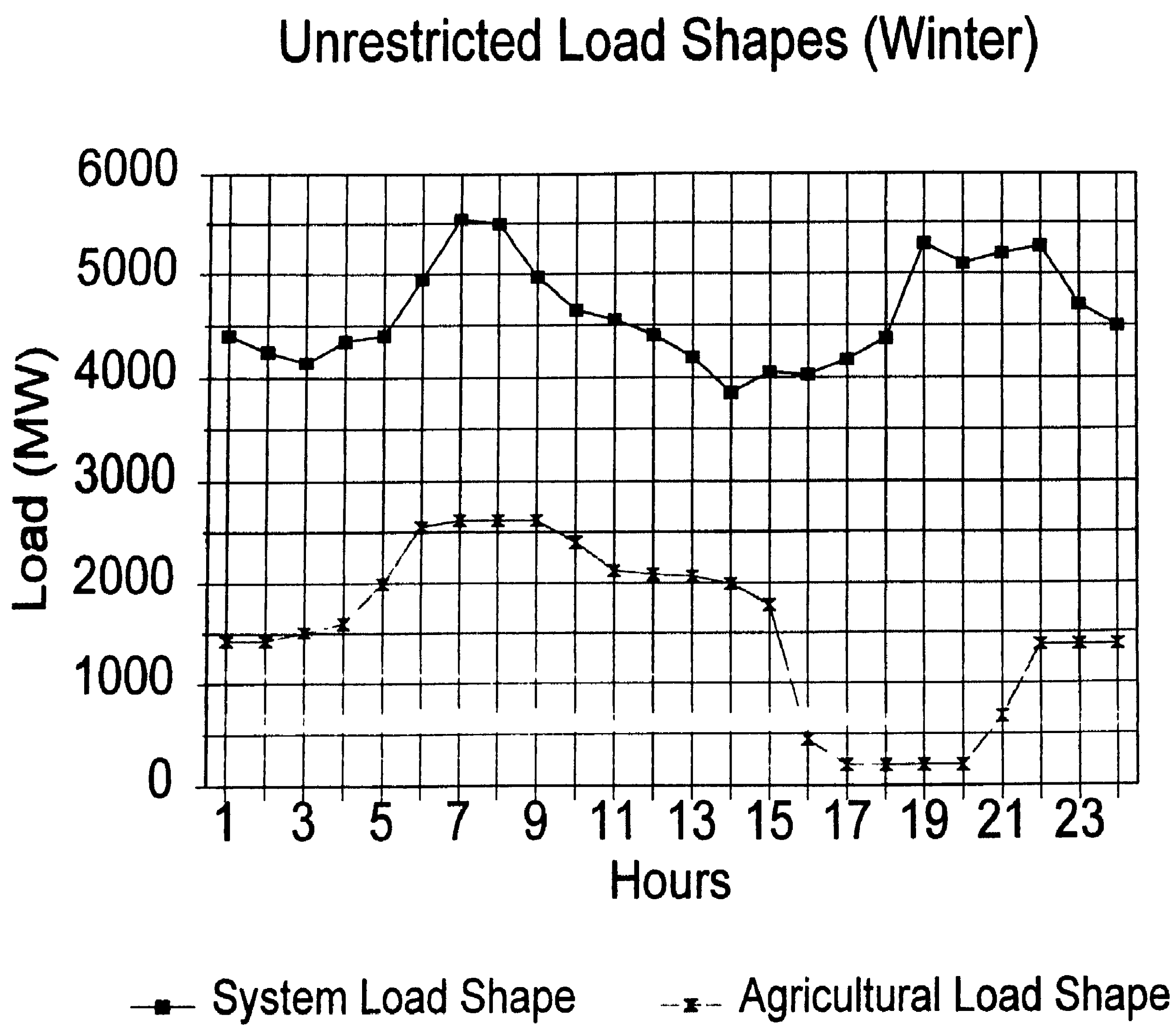

Unrestricted Load Shapes (Winter)
Load (MW)
6000
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
System Load Shape
Agricultural Load Shape

Figure 4.12

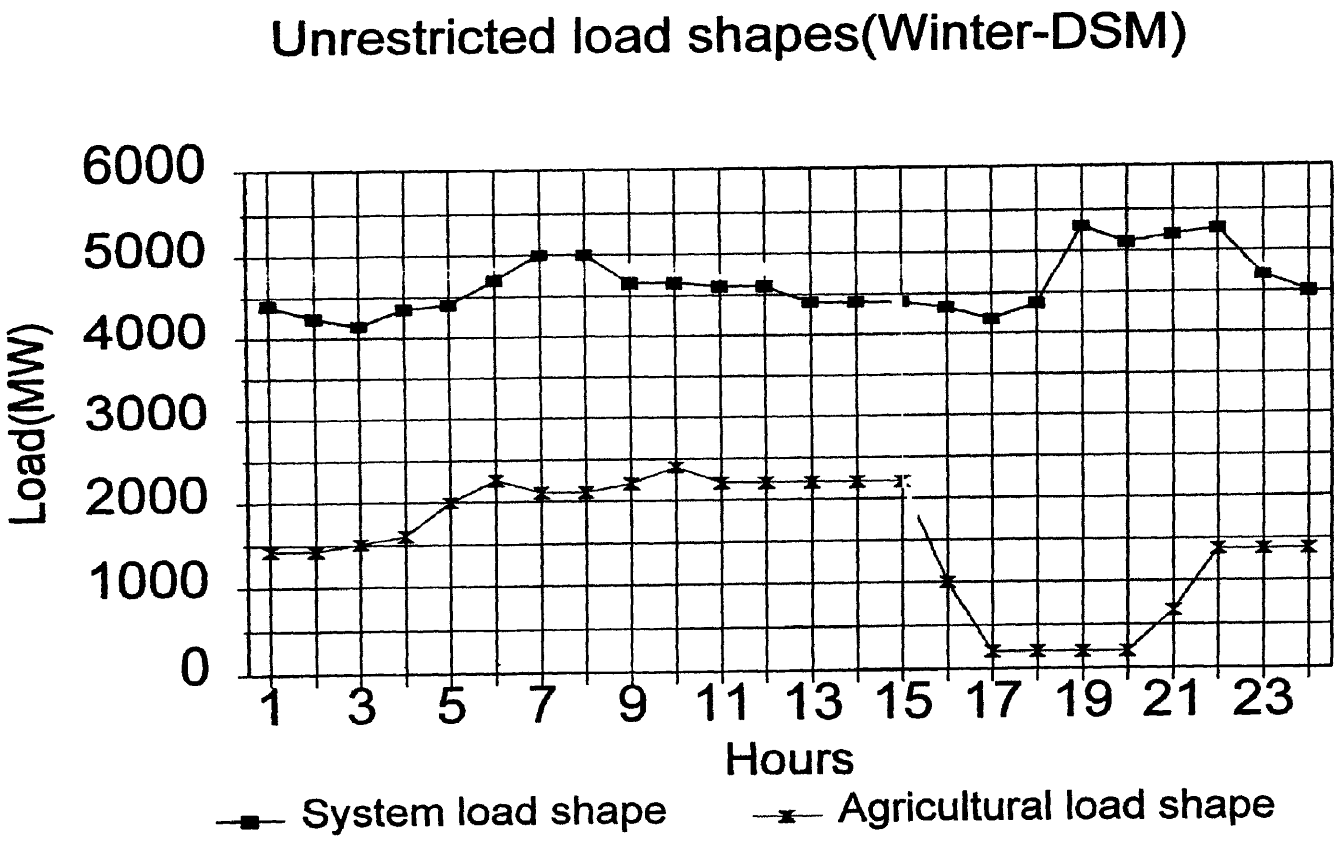
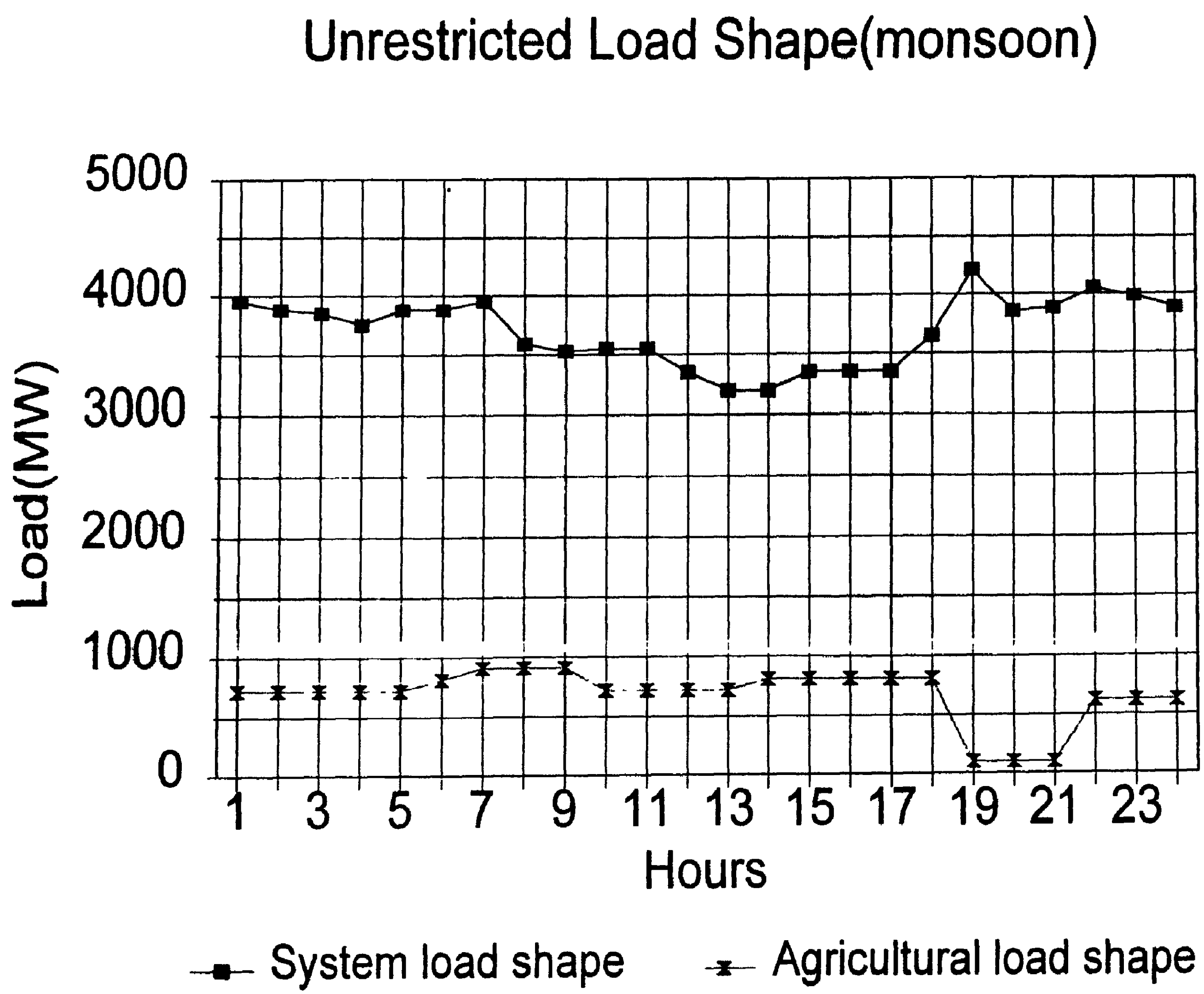

Unrestricted load shapes(Winter-DSM)
6000
5000
4000
3000
2000
1000
0
Load(MW)
1 3 5 7 9 11 13 15 17 19 21 23
Hours
System load shape
Agricultural load shape

Figure 4.12A



Unrestricted Load Shape(monsoon)
Load(MW)
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
System load shape
Agricultural load shape

Figure 4.13

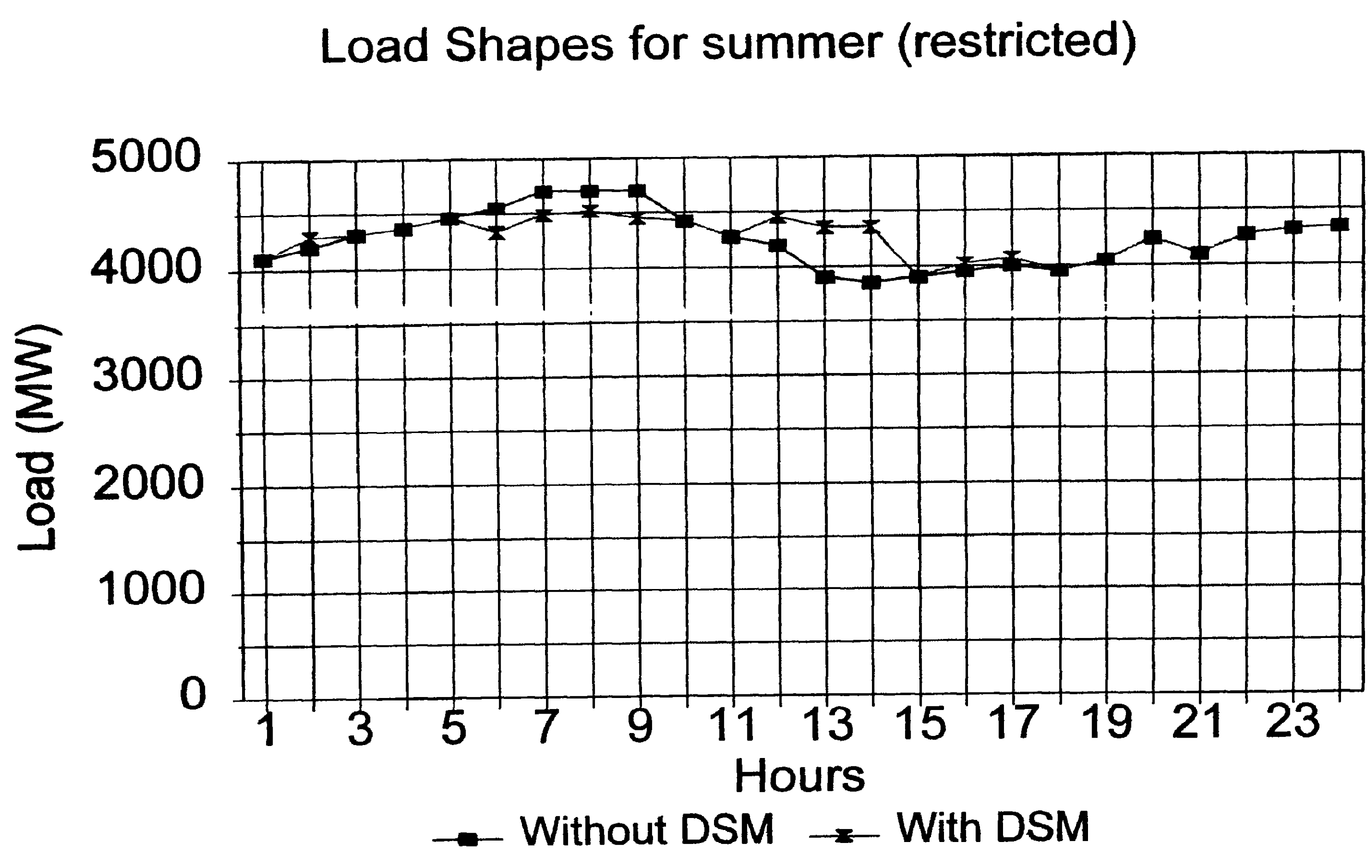

Load Shapes for summer (restricted)
Load (MW)
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Without DSM
With DSM

Figure 4.14

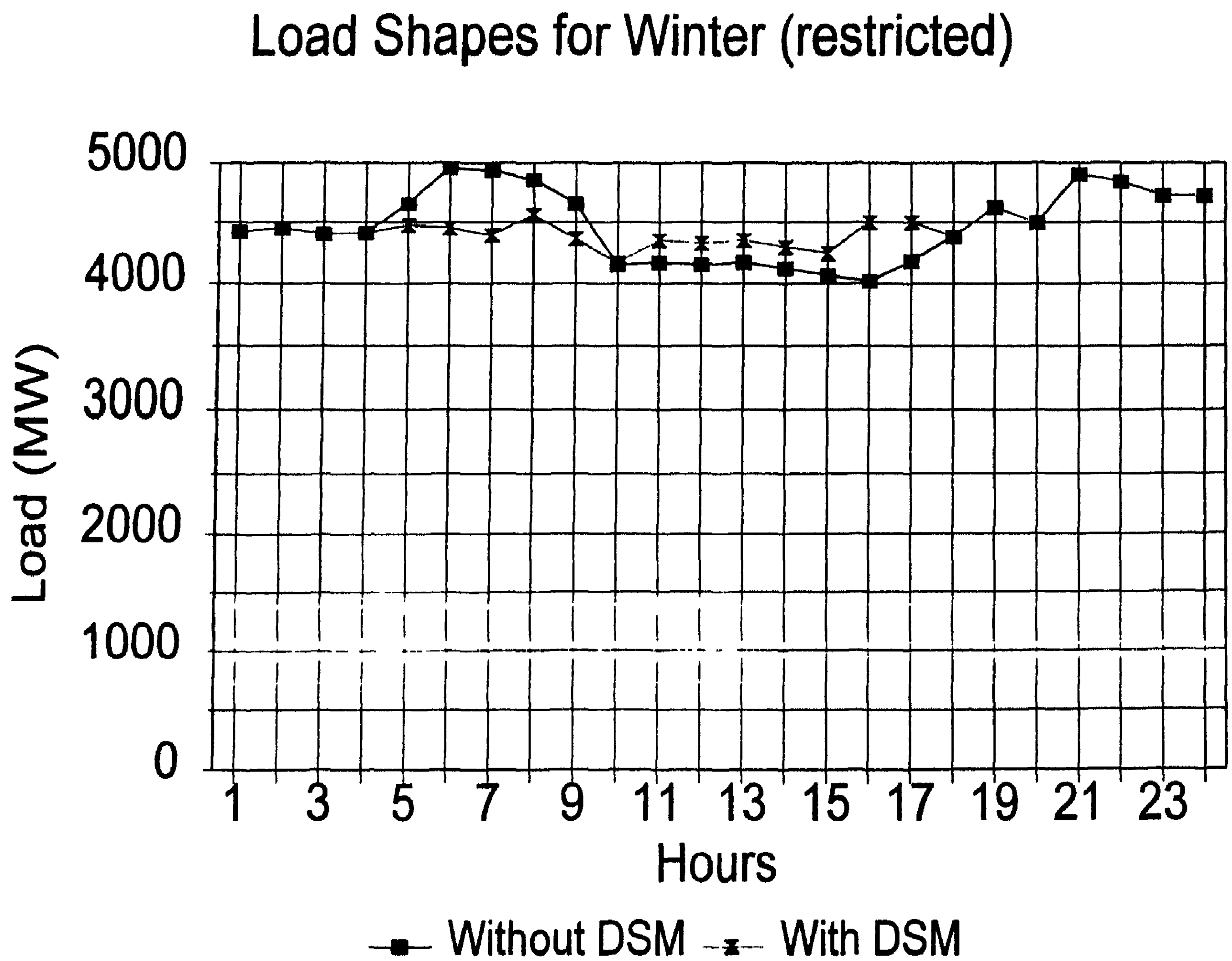

Load Shapes for Winter (restricted)
Load (MW)
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Without DSM
With DSM

Figure 4.15

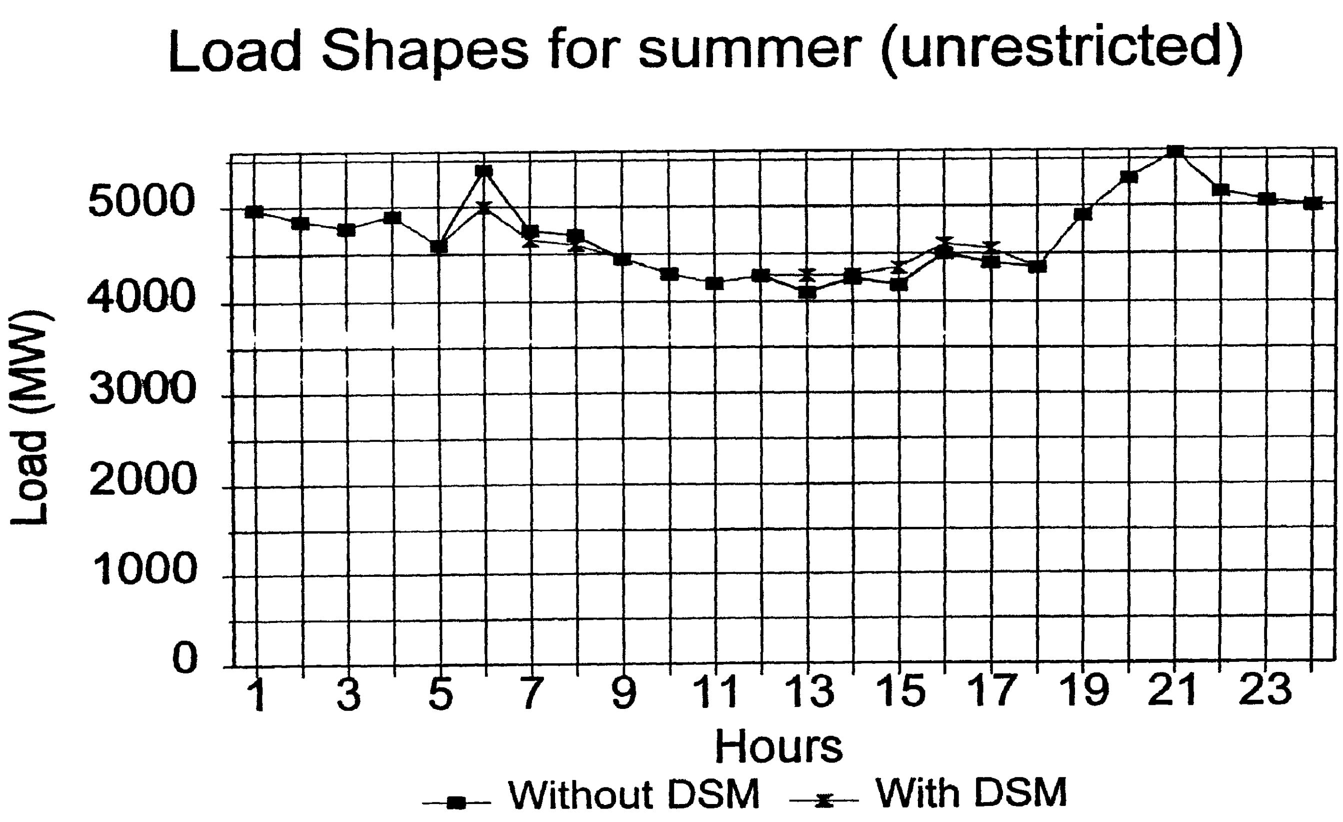

Load Shapes for summer (unrestricted)
Load (MW)
5000
4000
3000
2000
1000
0
1
3
5
7
9
11
13
15
17
19
21
23
Hours
Without DSM
With DSM

Figure 4.16